A Risk Analysis Tool for Evaluating ROI of TRA for Major Defense Acquisition Programs

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Dedication

I dedicate this dissertation to my loving and devoted family. Without your support and encouragement I could not have made this incredible journey. To my son, Reginald Lamont ("Lil Reggie"), and my daughter, Loryn Rashawn ("Peaches"), I am thankful because every day you have made me proud to be your father and friend. To my daughter-in-law, Evelin, and my son-in-law, Aaron, I am so very grateful for the love you share of this family, and for allowing this family to become a part of yours.

To my grandkids, Baby Reggie, Maya, and Baby Okken (on his way!), and for those that may follow, you've inspired me to be the best that I can be. I am so blessed and proud to be a part of your lives. I encourage each of you to take this torch and continue to spread the light, the blessings, the substance and joy of which you have been partakers, wherever life takes you, and make this world a better place for the generations that follow.

To my many nieces, nephews, and cousins know that there is no goal too big that you cannot achieve it. No mountain too high that you cannot scale it. No failure so terrible that you cannot overcome it. Seek out what God has in store for you, and take joy in the fact that He has a plan for you.

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Abstract

A Risk Analysis Tool for Evaluating ROI of TRA for Major Defense Acquisition Programs

The U.S. DoD budget has grown to over a half trillion dollars annually. Unfortunately, the majority of these acquisitions do not satisfy their initial performance objectives in terms of cost, schedule, and technical performance. The U.S. DoD attributes these shortfalls in part to the use of immature technologies within these programs. The U.S. DoD endorsed and later mandated the use of Technology Readiness Assessments (TRAs) and knowledge-based practices in the early 2000's to be used as a tool in the management of program acquisition risk. Unfortunately, the expense of implementing TRAs can be significant, especially when programs include knowledge-based practices such as prototyping, performance specifications, test plans, and technology maturity plans. What has been the economic impact of these TRA practices on the acquisition performance of the U.S. Army, Navy, and Air Force? The conundrum that exists today is there is no commonly accepted approach used to determine the economic value of TRAs. This study provides a model for the valuation of TRAs in assessing the risk of technical maturity. It provides a framework to evaluate the economic benefits of performing Technology Readiness Assessments on acquisition performance using cost and technology maturity risks to derive economic benefits, which can then be input into valuation techniques such as benefit/cost ratio, return on investment percentage, net present value, and real options analysis.

(Keywords: TRA, Knowledge-Based Acquisition, B/CR, ROI%, NPV, ROA)

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List of Acronyms

BEP.	Breakeven point
B/CR.	Benefit cost ratio
C/SCSC.	Cost/schedule control systems criteria
CPM.	Critical path method
CT.	Critical technology
DAS.	Defense acquisition system
DCF.	Discounted cash flow
DoD.	Department of Defense
DoDD.	Department of Defense directive
DoDI.	Department of Defense instruction
DoQ.	Delivery order quantity
DUSD.	Deputy Undersecretary of Defense
E&MD.	Engineering and manufacturing development
EVM.	Earned value management
FOM.	Figure of merit
GAO.	Government accountability office
IT.	Information technology
IRL.	Integration readiness level
IRR.	Internal rate of return
IRT.	Independent review team
ITP.	Integrated technology plan

MRL.	Manufacturing readiness level
MDA.	Milestone decision authority
MDAP.	Major defense acquisition program
MSA.	Materiel solution analysis
NASA.	National aeronautical space administration
NPV.	Net present value
NDI.	Non-developmental item
OAST.	Office of aeronautics and space technology
O&S.	Operation and support
PERT.	Program evaluation review technique
P&D.	Production and deployment
ROA.	Real options analysis
ROI.	Return on investment
ROI%.	Return on investment percentage
R&D.	Research and development
R&D3.	Research and development design difficulty
S&T.	Science and technology
SME.	Subject matter expert
SRL.	System readiness level
TNV.	Technology need value
TRA.	Technology readiness assessment
TRRA.	Technology readiness and risk assessment

TRL.	Technology readiness level
TD.	Technology development
U.S.	United States
WBS.	Work breakdown structure

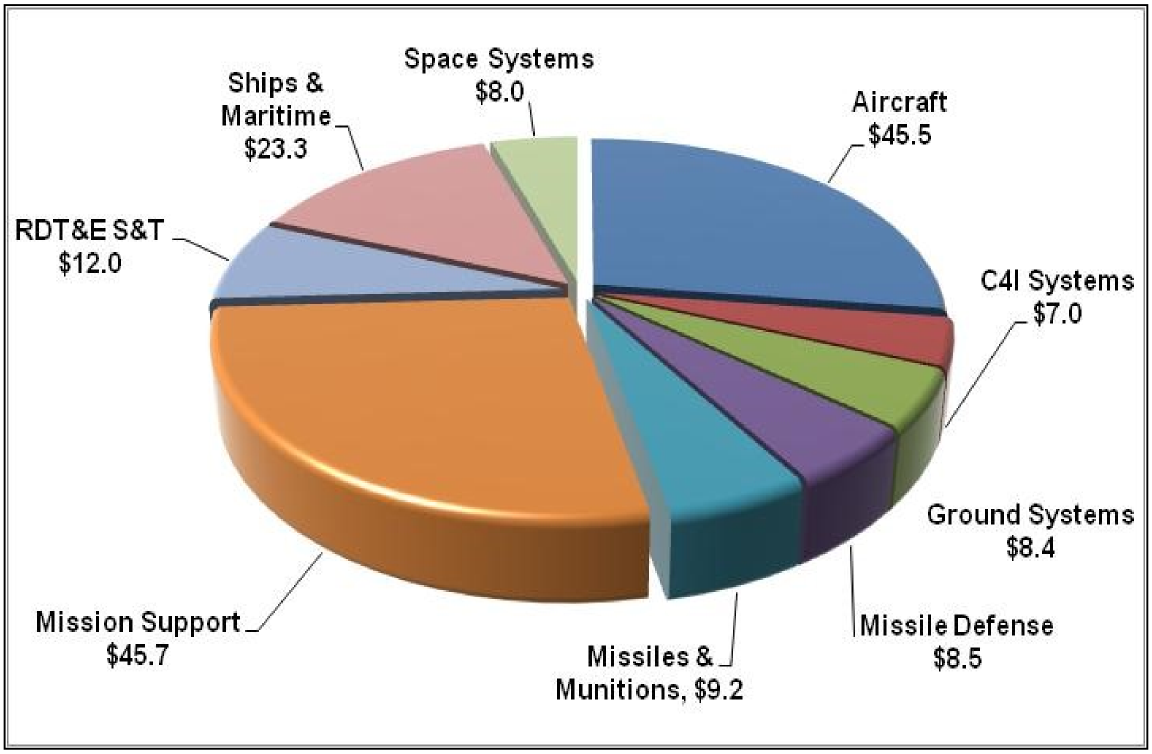
1 Introduction

1.1 Summary

The U.S. Government Accountability Office (GAO), formerly the General Accounting Office, has reported on the acquisition performance of major defense acquisition programs (MDAPs) since 1960 (GAO, 1988). From the inception of the U.S. GAO's mandate to report annually to Congress upon its assessment findings, the ability of the U.S. Department of Defense (DoD) to consistently execute its acquisition plan for the purchase of major weapon systems has been erratic, seldom meeting cost, schedule, or original performance objectives. From 1997 to 2012 the U.S. DoD budget grew by almost 200% to $529 billion representing more than 20% of the total operating budget of the U.S. Government (DoD, 2013a). Amazingly, thirty-one percent of all major defense acquisition programs (MDAPs) since 1997 have had either a significant or critical Nunn-McCurdy cost breach (DoD, 2013c). In addition during 1995-2013 each of the military services has had to cancel several major programs without receiving any or very few operational units for the funds expended (DoD, 2013c). Specifically the Army cancelled 14 MDAPs (i.e. ACS, ARH, ATACMS-BAT, C-27J (Army Portion), COMANCHE, CRUSADER, FCS, JCM, JTRS GMR (Army Portion), LAND WARRIOR, NECC, NLOS-LS, PATRIOT/MEADS CAP FIRE UNIT, SLAMRAAM). The Navy cancelled 7 MDAPS (i.e. ADS, ASDS, EFV, EP-X, ERM, F-35 Alt Engine (Navy Portion), VH-71). Finally, the Air Force cancelled 10 MDAPs (i.e. 3GIRS, C-130 AMP, C-27J, CSAR-X, E-10, ECSS, F-35 F136 Engine, NPOESS, SBSS Follow-on, TSAT).

As shown in Figure 1-1, about $167.6 billion will be allocated for the acquisition of approximately 65 MDAPs, representing just over 31% of the Fiscal Year 2014 U.S. DoD budget (DoD, 2013b). About 50 new military aircraft will be procured including 12 MQ-9A Reaper unmanned aerial vehicles and 20 F-35 fighter jets, in addition to nearly 8,200 missiles and other forms of munitions. System development cost overruns have doubled, total acquisition overruns have risen by four times, and schedule overruns have increased by 33%. Cost and schedule overruns typically manifest themselves in the form of reduced delivery order quantities or DoQs (GAO, 2009b; DoD, 2013c; Younossi et al., 2007). For instance, the U.S. DoD originally planned on procuring 650 F-22 fighter jets, but ended up with fewer than 200 after more than three decades and $90 billion (i.e., only 30% of the original orders were ever fulfilled). U.S. DoD decision makers believe that cost and schedule performance is a direct result of what is known as technology maturity, which is a metric that reflects the readiness of critical technologies to be used to meet program objectives (DoD, 2006). The U.S. DoD addresses technology maturity in two broad sweeping and highly-interrelated approaches. The first is the defense acquisition lifecycle, which is a five-stage process consisting of: (a) materiel solution analysis or MSA, (b) technology development or TD, (c) engineering and manufacturing development or E&MD, (d) production and deployment or P&D, and (e) operation and support or O&S (DAU, 2010). In this approach, it is believed that programs can reduce cost and schedule overruns with sufficient investments in basic research and development (R&D) and the construction of large-scale proofs of concept or system prototypes prior to detailed engineering design. Therefore, the U.S. DoD believes that most downstream errors are attributable to management and engineering effort committed in the early acquisition stages or lack of sufficient upstream investments in systems engineering activities at these early stages (DoD, 2008).

The second approach, which complements the first, is the practice of conducting Technology Readiness Assessments (TRAs) in these early stages. The U.S. DoD attributes a significant proportion of poor acquisition performance to the incorporation of immature technologies into its weapon system acquisitions by component agencies and their suppliers (DoD, 2008). The U.S. DoD spends millions of dollars each year performing TRAs as one of the approaches to monitor and control the perceived risk of incorporating immature technology into the acquisition process associated with its yearly multi-billion dollar expenditure for the procurement of military weapon systems. In particular, the U.S. DoD believes that critical technologies (CTs) should be identified during the TD phase, modeled within large-scale system prototypes, and measured using the technology readiness level (TRL) metric. A technology is considered critical if it poses a "major technological risk during development" (DoD, 2011a, p. 1-1). The U.S. DoD uses TRAs as a means of identifying critical technologies (CTs), and assessing their maturity using a Technology Readiness Level (TRL) scale (Mankins, 1995).



Source: Analysis of U.S. DoD 2013 Budget Allocation Data.

Figure 1-1. FY14 U.S. DoD Budget Allocation by Weapon System Type (in billions)

The TRL is a nine-point scale that measures the maturity or readiness of a critical technology, ranging from the most basic concept or idea stage through various stages of engineering development ending in successful mission operations. As part of a TRA, an independent team of subject matter experts (SMEs) assist the program manager in the process of identifying CTs believed to be the major drivers of cost and schedule performance during the acquisition, assessing component maturity and assigning TRLs, and documenting these results in a TRA report prior to the major decision making juncture in the overall defense acquisition life cycle (i.e. Milestone B) mandated by the Milestone Decision Authority (DoD, 2011a & 2011b). Each CT is assigned a TRL, with the goal of ensuring that CTs achieve the status of TRL 6 prior to the E&MD phase (i.e., system/subsystem model or prototype demonstration in a relevant environment). In other words, large-scale system prototypes prior to detailed engineering design should demonstrate critical technologies satisfy key performance requirements. Conversely, CTs that do not reach TRL 6 are considered principal drivers of acquisition performance risk and should be matured or removed from the weapon system design prior to E&MD (DoD, 2011a). Common CTs may be an advanced mission computer, fly-by-wire avionics system, low-observability coatings, fuel-efficient high-performance engines, etc. They are typically advanced or leading-edge technologies that will push the performance envelope of the weapon system and thus provide a strategic military advantage (Petraeus, 2010).

In 1999 the U.S. GAO defined a framework of acquisition practices modeled after commercial best practices that emphasized knowledge-based decision making, and recommended its adoption by the U.S. DoD (GAO, 1999). The U.S. DoD adopted knowledge-based practices in 2001 with the issuance of DoDD 5000.1 and DoDI 5000.2 (referenced now as 5000.01 and 5000.02). Starting in May 2003, and annually thereafter, the U.S. GAO has reported to Congress its assessment of the acquisition performance of major defense acquisition programs (MDAPs), emphasizing the U.S. DoD's use of mature technologies, TRAs, and that include adherence to knowledge-based acquisition practices such as prototyping, performance specifications, test plans, and technology maturity plans (GAO, 2003, 2004, 2005a, 2006, 2007a, 2008a, 2009a, 2010, 2011, & 2012). An MDAP is a program from the U.S. DoD portfolio with a R&D value greater than $365 million, or a procurement cost that is greater than $2.19 billion.

The U.S. GAO has produced numerous reports since its inception in 1921 about the efficiency, or lack thereof, of U.S. DoD spending and execution on major acquisition programs. In its 2011 report providing an assessment of selected weapons programs, the U.S. GAO indicated the number of MDAPs within the U.S. DoD portfolio between 2008 and 2010 had grown from 96 to 98 programs, with a total estimated worth of $1.68 trillion dollars (GAO, 2011). The 2010 MDAP portfolio increased in value by $135 billion, however, greater than 50% of the U.S. DoD portfolio did not meet cost objectives, and more than 80% had increased unit costs (GAO, 2011). These reports reflect a lack of efficiency of U.S. DoD spending and execution on major acquisition programs. In addition, MDAPs continue to experience increases of almost 24% in acquisition cycle time (GAO, 2007b).

The U.S. DoD believes that identifying and mitigating the use of immature technologies (i.e. TRL < 6) early is the key to improving overall acquisition performance (i.e., reducing cost and schedule overruns, increasing delivery order quantities, successful weapon system deployment, etc.) (GAO, 1998; GAO, 1999; DoD, 2011a; Cancian, 2010). This study however, based upon data derived from U.S. GAO research, reveals that during 2003-2012 only slightly more than half, 58.1%, of the CTs being used in development acquisitions were sufficiently matured (i.e. TRL >= 6). See Table 1-1. This tendency to proceed into development or production with less knowledge than required, has led to similar results experienced over the last five decades, with several programs failing to meet cost, schedule, and performance objectives originally established (Bair, 1994; GAO, 1988; Fox, 2011).

Table 1-1. 2003-2012 U.S. DoD CT Maturity Assessments

Year	Critical Technologies		
	Immature	**Total**	**Mature**
2012	103	345	70.1%
2011	106	371	71.4%
2010	105	372	71.8%
2009	177	420	57.9%
2008	208	466	55.4%
2007	241	451	46.6%
2006	225	428	47.4%
2005	251	443	43.3%
2004	193	391	50.6%
2003	39	117	66.7%
Avg	**165**	**380**	**58.1%**

Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012.

Utilization of proven technologies that offer moderate performance improvements, yet are well understood in order to meet scope, cost, schedule, and performance constraints, is the preferred acquisition approach of the U.S. DoD. However, currently the basic arguments in favor of applying the five-stage U.S. DoD acquisition life cycle defined by DoD (2008), upfront investments in large-scale system prototypes during the Technology Demonstration (TD) phase, and the performance of TRAs, along with identifying its associated CTs, assigning TRLs, and ensuring they reach sufficient maturity, may be considered qualitative at best and are primarily based on engineering judgment. Clausing & Holmes (2010) devised a structured technology readiness method which added quantification measures in an attempt to remove perceived subjectivity within NASA's TRL framework. However, little quantitative evidence has been collected on the actual economic benefits of technology maturity via TRAs for any of the military services, or the overall U.S. DoD. Therefore, the purpose of this study is to examine the wealth of information emerging from government agencies such as the U.S. GAO, U.S. DoD, and others, and apply economic models to begin examining the quantitative benefits of technology maturity for the major programs of the

U.S. DoD, and specifically of each of the military services. Indeed, by examining the real options method, this study provides a framework to estimate the economic value of performing TRAs against the risk of program development and system acquisition with immature technology. The results of this analysis should help members of the acquisition community determine whether TRA knowledge-based practices have a positive effect on the acquisition outcomes. More importantly, in these times of fiscally tight federal budgets, and the impact of the sequester, such evidence may also be of benefit to military strategists, if the use of TRAs indeed help reduce cost and schedule overruns and increase delivery order quantities (DoQs) for the Army, Navy, and Air Force (Petraeus, 2010).

1.2 Statement of Problem

There is a lack of scholarly research that evaluates the correlation between the return on investment (ROI) in acquisition programs for satisfying the U.S. DoD mandate requiring TRAs for all MDAPs as stipulated in DoDI 5000.02, and the performance of those programs (DoD, 2008). The importance of such research is that it will provide policy and decision makers with additional insight into the economic impact of applying formal TRAs and associated knowledge-based practices on the acquisition of major complex systems. As the cost and schedule of fielding major complex systems continues to increase, the need for the U.S. DoD to be more efficient and effective in its acquisition process has become more critical to its ability to provide for the defense of the nation. Each of the military services need to understand and follow best engineering practices to help mitigate the risks typically associated with the acquisition of MDAPs, specifically cost overruns, schedule delays, and system performance shortfalls. The inclusion of immature technology in development programs may lead to expenditure of financial resources that would be better spent on more viable and less risky programs within the U.S. DoD portfolio of MDAPs.

Although the U.S. DoD and U.S. GAO continue to surmise that the inclusion of immature technology into development programs is the primary source of cost and schedule overruns, there has not been any significant examination into the economic value of TRAs. As a result, the objective of this study was to provide a framework to assess the economic value, or ROI, of performing TRAs on MDAPs, and additionally with the use of real options analysis to provide insight for the decision maker in the management of the MDAP portfolio based upon the overall technology risk.

1.3 Relevance and Importance

Current literary research into the U.S. DoD's practice of utilizing TRAs in the acquisition of major systems and its economic return on investment is limited. Significant research has been conducted, however, illuminating the cost and schedule performance issues that have been experienced by a high proportion of the U.S. DoD MDAPs over the last 50+ years (Bair, 1994; GAO, 1988; Fox, 2011). The U.S. DoD's 2011 MDAP portfolio estimated total cost stood at $1.58 trillion. This cost represented approximately 5 percent, or $74.4 billion, growth in the estimated acquisition costs of the portfolio, and the average delay in delivering initially planned capabilities of 23 months (GAO, 2012). Cancian (2010, p. 397) posits that "cost growth acts like a tax, squeezing all acquisition programs and causing inefficiencies from reduced quantities and stretched schedules." Meier (2010) found in his research that inclusion of immature technology within a program development was one of the key factors that leads to cost overruns and schedule delays. Additional study by Honour (2004, p. 2), however, found that the adherence to optimal system engineering practices helps to reduce program "risk early…thereby reducing cost and shortening schedule."

The U.S. DoD, when updating its acquisition system via DoDI 5000.02, mandated the use of TRAs for all MDAPs as a means of mitigating risk associated with incorporating immature technology into major system developments (DoD, 2008). Implementing TRAs and associated knowledge-based practices requires systematic and disciplined adherence to good engineering principles (Azizian, Sarkani, Mazzuchi, & Rico, 2011a, 2011b). The associated cost of implementing TRAs may be as high as 10 percent of the total program cost. Only limited scholarly research has investigated the economic return on investment of investing in TRAs. This study is one of the first to examine the ROI of TRAs for MDAPs and its correlation with program performance. Also with the use of real options analysis, this study provides decision makers with a tool to assist managing risk within their program portfolios.

1.4 Contribution to the Body of Knowledge

The literature review, research framework, research methodology, data, and analysis, contained in this study contribute to the further expansion and illumination of understanding of the economic benefit of TRAs and knowledge-based practices comprised by a TRA process and mandated by DoDI 5000.02.

This study is one of the first of its kind to examine the economic value of performing TRAs for MDAPs. Other contributions include:

- One of first scholarly studies to apply real options analysis to the assessment of risk to MDAPs incorporating immature technologies within their development cycle.
- One of the first scholarly studies to highlight the apparent inconsistency between the military services in their implementation and adherence to TRAs and knowledge-based practices.
- Development of a tool to assist decision makers in the management of risk within their program portfolios.
- The research framework and associated preliminary data were presented at the 2012 Systems Engineering (SEDC) conference in Washington, D.C.

Further, this study provides valuable insight, as well as recommendations, into the type of additional research needed to enhance, assess, evaluate and improve the economic valuation of ROI for TRAs. Additional research can leverage this study to identify TRA attributes which provide greater ROI, and increased acquisition efficiency.

1.5 Rationale and Justification

The U.S. DoD is tasked to provide for the defense of the nation, and in so doing has developed a large portfolio of weapon systems that has established the U.S. as a superpower in the world of nations without peer. With the technological prowess the U.S. DoD has achieved however, it continues to have difficulty in acquiring major weapon systems within cost and schedule estimates, and at the level of performance originally envisioned (GAO, 2008b). Yet, from 1997 to 2012 the U.S. DoD budget grew by almost 200 percent to $529 billion representing more than 20 percent of the total operating budget of the U.S. Government (DoD, 2013a). Thirty-one percent of all major defense acquisition programs (MDAPs) since 1997 have had either a significant or critical Nunn-McCurdy cost breach (DoD, 2013c). In order to improve upon its performance in acquiring major complex systems, examination of all aspects of the defense acquisition process is necessary to provide additional insight to policy and decision makers in the management of U.S. DoD portfolio of programs. This study focuses upon the economic justification for implementation and adherence to TRAs and knowledge-based practices.

With the U.S. DoD, as well as the U.S. GAO, advocating the use of TRAs and knowledge-based practices as a means to mitigate technical and performance risk on MDAPs, there is a need to have supporting scholarly research that demonstrates the economic benefit that may be derived from following TRA knowledge-based practices. There is a need to provide additional insight to decision makers of the economic risk of proceeding into development with immature technology. This study provides the acquisition community with an initial indication of the commitment differences between the military services regarding implementation of TRA knowledge-based practices, and should serve as a catalyst for further research to understand the underlying reasons for this lack of consistency. Ultimately, this study will hopefully serve to provide the acquisition community both economic and technical performance incentives to more fully engage and implement TRA knowledge-based practices for all MDAPs.

1.6 Significance

The U.S. Congress, via the Clinger-Cohen Act of 1996, has required each government agency to maximize the return of its information technology (IT) acquisitions, and to more aggressively assess and manage the associated risks (Congress, 1996). Although there has been increased funding for the acquisition of MDAPs over the last 20 years, the acquisition performance has continued to suffer from cost overruns, schedule and performance shortfalls. The significance of this study is that it provides a framework for decision makers to obtain the economic insight into the risks being confronted within the MDAP portfolio, and to manage it accordingly. This study provides decision makers with a scholarly assessment of the economic benefit that may be realized given appropriate implementation of TRA knowledge-based practices. It will also provide insight into whether there is a correlation between the use of TRA knowledge-based practices and acquisition performance. It provides an initial economic examination of the implementation of TRA practices between the military services.

1.7 Organization of Document

This study is organized into seven chapters. The first chapter provides the Introduction, and explains the problem being studied; the second chapter provides the Background, and presents background information and motivation for conducting the research; the third chapter provides the Literature Review, and describes the key findings of the literature, and the fourth chapter presents the Research Framework, and describes the structural plan of the research used within the study. The fifth chapter provides the Research Methodology, and describes the procedures by which the research was conducted and presents the data analysis techniques utilized in the study. The sixth chapter provides the Data Analysis, and presents the detailed analysis of the data and reports on the results. The seventh chapter provides the Conclusion, and presents a discussion of the results followed by the conclusion, limitations, and recommendations for future research. An appendix has also been included providing the key source data used in this analysis.

2 Background

2.1 Research Problem

Effective decision aide tools have been sought and utilized by business management professionals to sustain and improve their competitive position. Whether to assist in the analysis of alternative investment strategies, or the performance characterization of technology development, better and more effective methods to support management decisions on appropriate courses of action are sought that help reduce and/or mitigate the uncertainty and risk involved with business development, and in particular technological development. The U.S. Department of Defense (DoD) is tasked to provide for the defense of the nation, and in so doing has developed a large portfolio of weapon systems that has established the U.S. as a superpower in the world of nations without peer. With the technological prowess the U.S. DoD has achieved however, it continues to have difficulty in acquiring major weapon systems within cost and schedule estimates, and at the level of performance originally envisioned (GAO, 2008b).

2.2 Research Background

The U.S. DoD budget has grown to nearly $529 billion annually. Acquisition performance continues to suffer from excessive cost and schedule overruns, reduced DoQs, and outright program cancellation. The U.S. DoD believes that technology maturity, or lack thereof, is a primary measure of acquisition performance (GAO, 2008b). That is, weapon systems that use mature technologies will have better acquisition performance than those using immature technologies. Technical maturity or knowledge-based practices as they're frequently called, such as the TD phase, full-scale system prototype, and TRA process together cost up to 10% of the acquisition expenses through the manufacturing phase. The fundamental theory is that these upfront technology maturity investments will head off downstream manufacturing, operating, and maintenance costs (DoD, 2006; DoD, 2008). However, most of these costs are incurred based on the inherent trust in the TRA process itself (i.e., they're taken on faith). Little data or information is actually available on the actual economic or hard-benefits of performing TRAs. Even those whom may be considered ardent supporters of TRAs want to quantify their economic benefits (Dubos, Saleh, & Braun, 2007; Kenley & El-Khoury, 2012).

Although economic valuation is a rather dated practice and many people now believe that qualitative or intangible benefits are of paramount importance, the use of economic valuation is experiencing a revival of sorts throughout the project management, engineering, information technology, and acquisition communities (Honour, 2004; Reinertsen, 2009). Among these, the most commonly cited measure of business value is the concept of return on investment or ROI (Morgan, 2005). However, there are some problems associated with ROI. First of all, some may attribute morale, trust, customer satisfaction, communication quality, collaboration, and other soft, non-quantitative measures to ROI. A smaller percentage of professionals may be aware of the mathematical or economic form of ROI. Contemporary economists feel the quantitative form of ROI is an unrealistic and perhaps an obsolete measure of economic performance due to its lack of consideration of the time value of money (Kodukula & Papudesu, 2006; Dixit & Pindyck, 1995). Therefore, economists promote other, more valid measures, such as net present value (NPV), internal rate of return (IRR), real options analysis (ROA), and numerous other measures of project performance (Tockey, 2004).

Today, there are hundreds of economic models from which to choose in assessing ROI and their numbers are growing every day. It's interesting to note that most of these methods are what is known as top-down parametric models, which require only a few basic inputs, such as costs, benefits, interest rate, time horizon, or even risk. The key inputs, of course, are costs and benefits. Cost data is being collected in increasing frequency and soft or non-quantitative benefits are sometimes collected as well. It's only when the latter are converted into economic terms or monetized, that the plethora, suite, or portfolio of economic equations and models may be applied. In spite of the myriad of complex economic methods, a few basic forms seem to be standing the test of time (i.e., NPV, B/CR and ROI%). Both B/CR and ROI% may be considered too optimistic because they do not incorporate the time value of money, and NPV may be considered too pessimistic because it does not consider the financial potential of managerial risk taking. A relatively new economic model, ROA often mirrors B/CR and ROI%, because it adds value back to the sum due to the presence of risk and its estimation curve isn't quite so steep.

2.3 Purpose

The U.S. DoD endeavors to ensure that suppliers aren't incorporating vaporware into their weapon system designs that will later cause cost and schedule delays in order to move these ideas beyond the creative imaginations of research scientists. The U.S. DoD seeks rather to have proven technologies that offer moderate performance improvement, and are well beyond the idea stages, in order to meet scope, cost, schedule, and performance constraints. However, to-date the basic arguments in favor of applying the five-stage U.S. DoD defense acquisition system life cycle, upfront investments in large-scale system prototypes during the TD phase, and the performance of TRAs, along with identifying its associated CTs, assigning TRLs, and ensuring they reach TRL 6, are qualitative at best and are primarily based on engineering judgment or face validity. Little quantitative evidence has been collected to-date on the actual economic benefits of technology maturity via TRAs. Therefore, the purpose of this study was to examine the recent slew of acquisition performance data emerging from government agencies such as the U.S. Government Accountability Office (GAO), as well as other sources, and apply economic models to begin examining the quantitative benefits of technology maturity. The results of this analysis should help U.S. DoD decision makers, acquisition program managers, systems engineers, and researchers determine whether acquisition best practices have a positive effect on acquisition outcomes. More importantly, such evidence would also be interesting to military strategists, if the use of TRAs help reduce cost and schedule overruns and increase DoQs (Petraeus, 2010).

2.4 Research Questions

The basic research problem or question investigated in this study is what are the economic benefits of applying TRAs to U.S. DoD acquisitions? More specifically, what is the cost of TRAs? What is the benefit of TRAs? What is the benefit/cost ratio of TRAs? What is the ROI% of TRAs? What is the NPV of TRAs? What is the breakeven point of TRAs? What is the ROA of TRAs? Consequently, the fundamental goal and objective of this study is to collect, examine, and analyze U.S. DoD acquisition data, apply some of these basic economic models, and explore the economic value of applying TRAs to U.S. DoD acquisitions.

2.5 Scope and Limitations

Although studies by the U.S. GAO, along with this study, are beginning to emerge, which show improved acquisition performance and economic benefits of knowledge-based practices, there is still much work to be done. For instance, better and finer grained data need to be collected on the precise investment costs associated with the TD phase, full-scale system prototypes, and the TRA process itself. Furthermore, while the U.S. GAO studies provide early broad-sweeping estimates of the benefits of knowledge-based practice, micro-economic studies of the impacts, outcomes, and benefits of technology maturity still need to be performed. Of course, data quality is the key to any quantitative analysis, so the assumptions behind the acquisition data need closer scrutiny, examination, and justification. This study is designed to begin the conversation associated with those who wish to understand the quantitative economic benefits of TRAs, rather than end it. This study is not intended to be an exhaustive economic evaluation of the costs and benefits of TRAs, but rather it is intended to be an initial exploratory investigation into the economic benefits of TRAs. And, of course, this is not a definitive analysis of the costs and benefits of TRAs. That being said, this study still provides significant progress towards understanding these dynamics.

3 Literature Review

3.1 Summary of Literature

Effective decision aide tools have been sought and utilized by leaders and business management professionals to sustain and improve their competitive position. Whether to assist in the analysis of alternative investment strategies, or the performance characterization of technology development, better and more effective methods to support management decisions on appropriate courses of action are sought that help reduce and/or mitigate the uncertainty and risk involved with business development, and in particular technological development. The U.S. Department of Defense (DoD) is tasked to provide for the defense of the nation, and in so doing has developed a large portfolio of weapon systems that has established the U.S. as a superpower in the world of nations without peer. With the technological prowess the U.S. DoD has achieved however, it continues to have difficulty in acquiring major weapon systems within cost and schedule estimates, and at the level of performance originally envisioned (GAO, 2008b).

This chapter provides the context for the relevance of this study with regard to the current literature. The literature research for this study encompassed a wide assortment of sources, including government and professional studies, white papers, conference articles, academic research papers, text books, and journal articles, as well as U.S. government and DoD policies and regulations. Given the scope of this research, this chapter has been organized to initially discuss the history of U.S. Government acquisition and systems engineering of major defense acquisitions systems, followed by a short history of technology readiness assessment (TRA), and lastly followed by an historical summary of quantification methods of economic value.

3.2 History of Government Acquisition & Systems Engineering

The U.S. Congress brought into existence the U.S. Government Accountability Office (GAO), formerly the General Accounting Office, with the enactment of the Budget and Accountability Act of 1921 (aka "The General Accounting Act of 1921"). A primary goal of this legislation was to centralize the budget process and provide Congress with more transparency into the expenditures of the federal government. It separated the U.S. GAO function from that of the Executive branch, and required the President to provide an annual budget of the federal government to Congress (Congress, 1921). Concern about the effectiveness of the defense acquisition system has been a recurrent theme of reports and initiatives for many generations. In 1960 the U.S. GAO was requested to provide a review of the acquisition of Army combat and tactical vehicles. That review disclosed that several series of vehicles were seriously deficient in operational performance (GAO, 1960). In 1969 the U. S. GAO published a report in which it emphasized the need to improve the management of major weapon systems based upon the acquisition performance of several Army tank vehicles and components failing to achieve their original performance objectives (GAO, 1969). In the intervening five decades since 1960 until this study, multiple reports have been generated, multiple initiatives instituted, multiple reforms established in efforts to improve the U.S. DoD acquisition of major weapon systems, however the results have only resulted in marginal improvement in overall acquisition performance of the U.S. DoD.

The inability of the U.S. DoD to perform effectively and efficiently on a sustained basis across its portfolio of MDAPs is certainly a complex and multifaceted issue with multiple attributes. Thomas McNaugher asserted that "acquisition reform does not work, or it works mainly to create problems that prompt still more reforms" (McNaugher, 1987, p. 65). Indeed, a review of the literature reveals some of the issues confronted by the U.S. DoD in its acquisition program are not only technology based, but political as well. For instance, analysis by Fox (2011, p. XII) indicated "Most attempts to implement improvements in the management of the defense acquisition process during the past fifty years have fallen short of their objectives. It is increasingly evident that barriers to improving the acquisition process derive, not from a lack of ideas, but from the difficulties encountered by senior government managers (in Congress as well as in the Department of Defense) in identifying and changing counterproductive incentives for government and industry."

The U.S. Department of Defense (DoD) portfolio of major defense acquisition programs (MDAPs) was comprised of 95 programs as of 2013, with an estimated cost for development and procurement of nearly $1.7 trillion (DoD, 2013a). From 1997 to 2012 the U.S. DoD budget grew by almost 200% to $529 billion annually, representing more than 20% of the total operating budget of the U.S. government (DoD, 2013a). The U.S. GAO has reported on the acquisition performance of major defense acquisition programs since 1960 (GAO, 1988). From the inception of the U.S. GAO's mandate to report annually to Congress upon its assessment findings, the ability of the U.S. DoD to consistently execute its acquisition plan of major weapon systems has been erratic, seldom meeting cost, schedule, or original performance objectives.

As the TRA enters its 40th year, more and more scientists, economists, leaders, managers, engineers, and researchers are seeking to quantify the business value of TRAs (Azizian, Sarkani, Mazzuchi, & Rico, 2011a, 2011b). The popularity of measuring the business value of investments in new systems, projects, and acquisitions has been growing in recent years and decades. As shown in Figure 3-1, methods to help plan and manage acquisitions, measure intermediate results, and ultimately improve acquisition performance have been emerging over the last 70 years (Fox, 2011). Tracing back to the 1950s, the critical path method (CPM) (1957) and the program evaluation review technique (PERT) (1958) were introduced in support of programs such as the U.S. Navy's Polaris submarine. In the 1960s, key approaches like the work breakdown structure (WBS) (1962) and cost/schedule control systems criteria (C/SCSC) (1967), which later became known as earned value management (EVM) to better understand in-process cost and schedule performance, were introduced. In 1969, the U.S. DoD published MIL-STD-499 to provide systems engineering guidance for the development its programs (DoD, 1969). In the 1970s, the U.S. Army introduced its systems engineering management plan standard, FM770-78. In 1988, DoD-STD-2167A was introduced to establish development guidelines for software (DoD, 1985). In the 1990s, DoDI 5000.02 was issued to revamp the Defense Acquisition System (DAS) in part to reaffirm the use of

EVM. Later, the U.S. Congress, via the Clinger-Cohen Act of 1996, required each government agency to maximize the return of its information technology (IT) acquisitions, and to more aggressively assess and manage the associated risks (Congress, 1996). Barry Boehm's Spiral Model (1988) was also incorporated into DoDI 5000 in the form of evolutionary acquisition principles during this timeframe (Reagan & Rico, 2012; Slate, 2002; DoD, 2007). In the 2000s, DoD Directive 8115.01 was issued, which instructed each of the military services to manage their IT investments as portfolios to maximize ROI to the enterprise (DoD, 2005). In a 2007 report, the U.S. GAO recommended that the U.S. DoD implement an integrated portfolio management strategy for weapon systems investments to maximize ROI (GAO, 2007b). DoDI 5000.02 was introduced in 2008 enhancing DAS acquisition practices and mandating the use of TRAs to help ensure only mature technologies were incorporated into the U.S. DoD's portfolio of MDAPs (DoD, 2008). In 2009, the U.S. Congress enacted the Weapon Systems Acquisition Reform Act requiring all critical technologies be sufficiently mature (i.e. >= TRL 6) before entering into the development phase (DoD, 2011a). Most recently, the U.S. DoD instituted the Better Buying Power Initiative (2010 & 2012) to encourage the use of management methods to achieve greater efficiency and productivity (DoD, 2010; DoD, 2012).

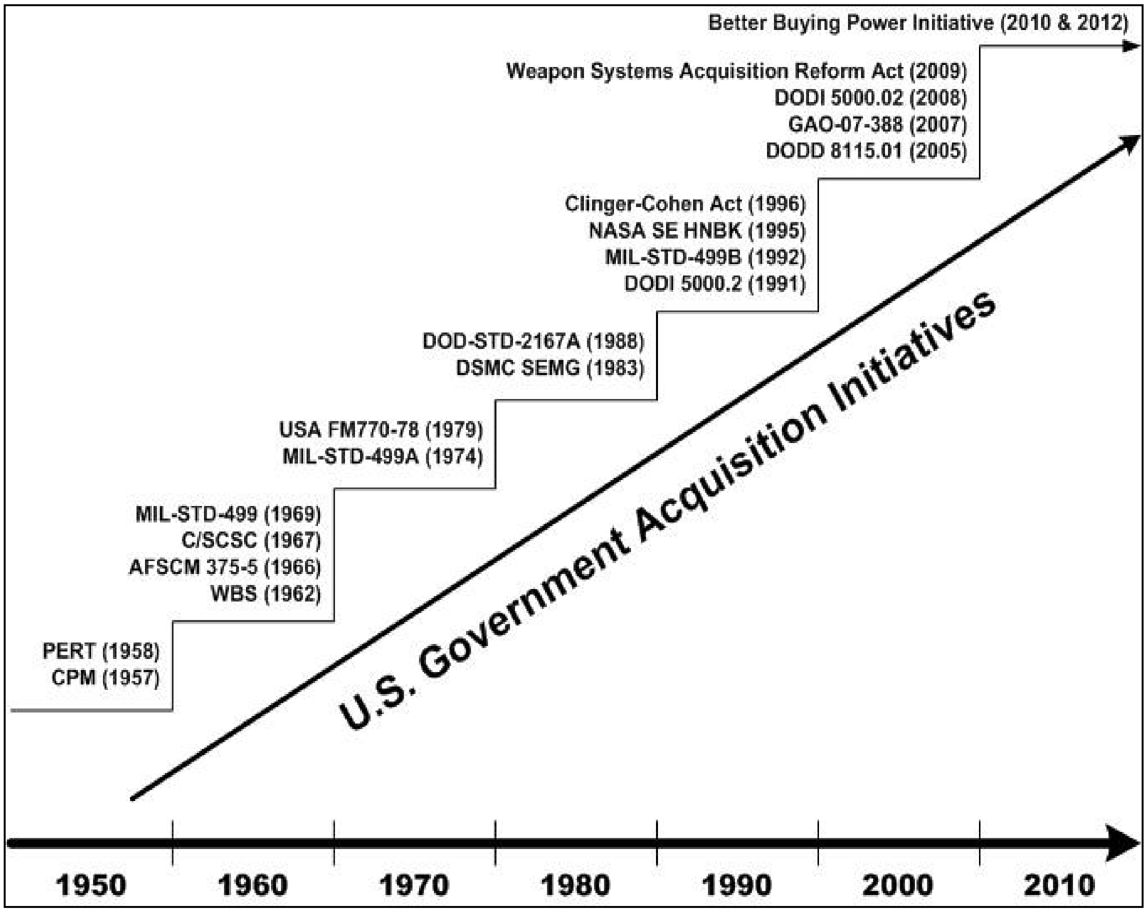


Figure 3-1. Timeline of the Evolution of Government Acquisition Initiatives

A TRA is a systematic, metrics-based process that assesses the maturity and risks associated with critical technologies to be used in MDAPs (DoD, 2011a). The original 7-level TRL was devised by Stanley Sadin during the late 1970s at NASA's Office of Aeronautics and Space Technology (OAST) as a means to assess technology maturity and provide a more consistent framework in which to compare technologies. By 1989, the 7-level TRL scale was formalized and later incorporated into NASA's Integrated Technology Plan (ITP) for civil space programs in 1991 (Sadin, Povinelli, & Rosen, 1989). In 1995, John C. Mankins extended the TRL scale into 9-levels and strengthened the definition of each TRL by adding better descriptions and practical examples (Mankins, 1995). In 1999, the U.S. GAO recommended adoption of the TRL scale by the U.S. DoD as a means to improve the quality and acquisition performance of their programs (GAO, 1999).

This recommendation was endorsed by the Deputy Undersecretary of Defense for Science and Technology (DUSD S&T) in July 2001 as the tool of choice in assessing the technology maturity of MDAP critical components. U.S. DoD decision makers believe that technology maturity is a major driver of acquisition performance and the use of mature technologies reduces cost and schedule overruns, while immature technologies increase them (DoD, 2011a).

Today, there are many variations of TRLs with tailored scales for hardware, software, manufacturing, medical devices, nuclear energy, pharmaceuticals, petrochemicals, etc. TRLs have even been expanded into manufacturing readiness levels (MRLs), integration readiness levels (IRLs), and system readiness levels (SRLs) to evaluate the maturity of interfaces between individual technologies (Cundiff, 2003; Sauser, Verma, Ramirez-Marquez, & Gove, 2006). Others, such as Clausing & Holmes (2010), have devised structured technology readiness methods which add quantification measures like failure modes, critical parameters, and latitude in attempts to remove perceived subjectivity within NASA's TRL framework. However, the U.S. DoD and U.S. GAO continue to support the use of its TRA process and age-old 9-level TRL scale (DoD, 2007, 2008, & 2009), in lieu of the newer mathematical techniques such as SRLs which only provide incremental gains (Kujawski, 2013; McConkie, Mazzuchi, Sarkani, & Marchette, 2012).

The U.S. DoD believes that identifying and mitigating the use of immature technologies (i.e. TRL < 6) early is the key to improving overall acquisition performance (i.e., reducing cost and schedule overruns, increasing delivery order quantities, successful weapon system deployment, etc.) (GAO, 1998; GAO, 1999; DoD, 2011a; Cancian, 2010). However, in reviewing the Selected Acquisition Reports produced by the U.S. GAO during 2003-2012, only slightly more than half, 58.1%, of the Critical Technologies (CTs) being used in development acquisitions were sufficiently matured (i.e. TRL >= 6) (GAO, 2003, 2004, 2005a, 2006, 2007a, 2008a, 2009a, 2010, 2011, & 2012). See Table 3-1. This tendency to proceed into development or production with less knowledge than required, has led to similar results experienced over the last five decades, with several programs failing to meet cost, schedule, and performance objectives originally established (Bair, 1994; GAO, 1988; Fox, 2011).

Table 3-1. 2003-2012 U.S. DoD CT Maturity Assessments

Year	Critical Technologies		
	Immature	**Total**	**Mature**
2012	103	345	70.1%
2011	106	371	71.4%
2010	105	372	71.8%
2009	177	420	57.9%
2008	208	466	55.4%
2007	241	451	46.6%
2006	225	428	47.4%
2005	251	443	43.3%
2004	193	391	50.6%
2003	39	117	66.7%
Avg	**165**	**380**	**58.1%**

Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012.

Although there have been many attempts at improving and reforming the U.S. DoD acquisition system over the last several decades, the results seem to show an intractable complex of challenges that have proven resistant to change, leaving cost growth, schedule slippage, and performance shortfall as the three persistent pillars of obstinacy to acquisition success. In each of the last 5 decades the defense acquisition system may be characterized as having a pattern of analysis, and assessment, followed by initiatives, directives, and laws in the hopes of reforming, and improving the efficiency and effectiveness of the acquisition process of major weapon systems (GAO, 1988; Fox, 2011; Bair, 1994; McNaugher, 1987). From the establishing of the Department of Defense in 1947 to facilitate better cooperation and administration among the military services, to the Better Buying Power initiatives of 2010/2012 emphasizing obtaining better value for the taxpayer (see Table 3-2), most of these actions have had limited success in improving the results of the defense acquisition process (DoD, 2010; DoD, 2012).

In a 2006 report on defense acquisition performance the U.S. DoD posited that “despite frequent reform and some isolated successes, the overall performance of the <Defense> Acquisition System remains problematic.” (DoD, 2006, p. 34) Bair (1994) alludes to the issue that the defense acquisition system not only suffers from attempting to acquire very complex technological systems, but also wrestles with satisfying non-technical socioeconomic concerns such as small and minority business support, and protecting domestic industries. Fox (2011, p. 206) warns that “it is increasingly evident that the schedule, cost, and technical performance problems of defense acquisition programs conducted by thousands of government and industry participants will not be corrected by short-term fixes.”

Table 3-2. U.S. DoD Major Acquisition Reforms and Initiatives (1947-2012)

Timeframe	Watermark Event	Key Results
1947-1959	National Security Act of 1947	Created Department of Defense; mitigation of inter-service rivalry
	Defense Reorganization Act of 1958	Broadened power and increase staff of SecDef
1960-1969	Selected Acquisition Reporting system established (1968)	Provided progress insight to Congress of ongoing acquisitions
	Defense Systems Acquisition Review Council established (1969)	Established to advise SecDef on the health/status of acquisition program at milestone gates A/B/C
1970-1979	GAO issued first series of annual reports on status of weapon system acquisitions (1970)	Provided independent audit of selected weapon system acquisitions
	Blue Ribbon Defense Panel (Fitzhugh Commission) (1970)	Loosened power centralization in DoD, Total Package Procurement elimination
	Cost Analysis Improvement Group (1972)	Provided independent review of acquisition cost estimates at major milestones
	Congressional Commission on Government Procurement (McGuire-Holifield Commission) (1972)	Established Office of Federal Procurement Policy to facilitate best practices and processes used across government
1980-1989	Carlucci Thirty-Two Acquisition Initiatives (1981)	Centralized acquisition policy planning, decentralized policy execution
	Defense Authorization Act Nunn-McCurdy Amendment (1982)	Required notification of Congress when a program is 15% above original target cost, and termination when a program is 25% above target cost unless rationale provided be SecDef
	The Grace Commission (1983)	Provided 2478 recommendations on how to eliminate government wasteful spending and abuse, including U.S. DoD acquisition practices.
	Competition in Contracting Act (1984)	Required, with limited exceptions, full and open competition for all U. S. Government contracts.
	Blue Ribbon Commission (Packard Commission) (1986)	Recommended several acquisition reforms including strategy of "Fly before you buy", effectively maturing technology innovations before inserting them into development programs.

	Goldwater-Nichols DoD Reorganization Act of 1986	Restructured U.S. DoD hierarchy with focus on greater efficiency and effectiveness across the U.S. DoD enterprise. Established Office of the Secretary of Defense (OSD), as well as a position of Director of Defense Research and Engineering.
1990-1999	Clinger-Cohen Act (1996)	Encouraged use of industry best practices in the acquisition of systems while seeking to maximize return on investment.
	GAO institution of knowledge-based procurement practices (1999)	Endorsed and recommended to U.S. DoD use of knowledge-based procurement practices within government acquisitions.
2000-2009	DoDI 5000.02 (originally 5000.2 in 2000; revised to in 2008 to 5000.02)	Mandated use of knowledge-based procurement practices, specifically requiring assessment of technology maturity at major milestone(s) of the revamped Defense Acquisition System.
	DoDI 8115.02 (IT Portfolio Management) (2005)	Mandated military services to manage their IT investments as portfolios emphasizing maximization of return on investment for the enterprise.
	Weapon System Acquisition Reform Act (2009)	Mandated establishment of technological maturity standards, and that technology readiness assessments be administered by DDR&E at key stages of a development.
2010-	Better Buying Power 1.0 Initiative (2010)	Encouraged acquisition focus to be efficient and effective with an overall goal of achieving mission objectives at an affordable cost and schedule; doing more without more.
	Better Buying Power 2.0 Initiative (2012)	Established 36 initiatives organized into 7 focus areas of the acquisition process. Emphasized use of the Technology Development phase for true risk reduction.

Source: Adapted from enumerated reforms and initiatives

Focusing in upon a few of the latest initiatives since 2000, we see a growing trend of directional guidance to make use of knowledge-based acquisition practices. DoDI 5000.02

mandated the use of technology readiness assessments for major defense acquisition programs to help assess the maturity of critical technologies at major program decision points. It established evolutionary acquisition as the "preferred U.S. DoD strategy for rapid acquisition of mature technology" (DoD, 2008, p. 13). It advocated a disciplined approach to incorporating new technologies into the development of major programs, helping to mitigate and distribute risk over a longer period of time by allowing critical technologies to sufficiently mature. DoDI 8115.02 in an attempt to emulate best commercial practices, directed and encouraged the use of portfolio management strategies to maximize the return on investment at the enterprise level of each of the military service departments (DoD, 2005). It was intended to support key decision making on possible investments (or continued investments) into major defense programs. It provides the opportunity for decision makers to delay, abandon, expand, or reduce investments based upon current information regarding the program risk and its relative performance when compared with other programs within the department's enterprise portfolio. In 2009, the Congress enacted the Weapon Systems Acquisition Reform Act. It mandated the use of technology maturity standards, including prototyping of critical technologies for MDAPs, and a technology readiness assessment administered by the Director of Defense Research and Engineering (DDR&E) (Congress, 2009). The Better Buying Initiatives of 2010 and 2012 encouraged prudent financial management of the portfolio of programs within the U.S. DoD. They encouraged focus on being efficient and effective with an overall goal of achieving mission objectives at an affordable cost and schedule; doing more without more. Affordability was mandated as a requirement at all milestone decision points (DoD, 2010; DoD, 2012). The full impact of these most recent acquisition initiatives is still evolving. The increased emphasis on knowledge-based practices, including TRAs and prototyping of critical technologies early in the program lifecycle is starting to show promise.

3.3 History of Technology Readiness Assessment

Gordon Moore, a former chairman and co-founder of Intel Corporation, once predicted (circa 1965) that the number of transistors on an integrated circuit would double every 2 years. Ray Kurzweil, a noted futurist, author, and technology innovator, predicted that the rate of growth of human knowledge, and in computing specifically, would continue to increase not linearly, but exponentially (Kurzweil, 2001). Secretary of Defense William Perry, in the face of world political and economic change, in a 1994 memorandum entitled "Specifications & Standards- A New Way of Doing Business", pushed to take advantage of the rapid pace technology advancement, and the COTS products and processes available in the commercial space vs. continue to rely on the unique costly requirements embodied in many of the engineering military standards in use (DoD, 1994).

The concept of technology readiness was initially introduced and advocated by U. S. National Aeronautical Space Administration (NASA) in the late 1980's as the agency sought to rebuild and refine it development processes in light of the U.S. Space Shuttle Challenger accident. In 1989, Stanley Sadin et al., articulated a list of 7 readiness levels as a "basis for developing mutual understandings and technology handoff agreements between research personnel, research management, and mission flight managers" (Sadin, 1989). The technology readiness assessment (TRA) has become recognized as a best business practice in the management of program risk associated with technology development (Sadin, 1989; Mankins, 1995).

To better understand the significance and context of Sadin's TRA creation, it may be worthwhile to look closer at the development and use of technology, and its impact on the world throughout this history of mankind. Technology has been used by mankind for millennia to improve his/her environment, increase its security, and explore the world (terrestrial and extraterrestrial), to explore space (inner and outer), and to increase the body of knowledge of the world in which they live. The knowledge has been used for good, saving and making better the lives of generations that followed, and the knowledge has been used for bad, destroying the lives of millions. Technology has allowed mankind to improve his surroundings, transforming dry lands to rich agricultural sources of food to supply not only individuals, but cities, states, and nations. Technology has allowed mankind to evolve from a nomadic, hunting culture to a more settled, social, and communicative civilization that has facilitated the expansion of the human body of knowledge, and the pace of acquisition of new knowledge. As mentioned earlier, Ray Kurzweil has noted that the pace of innovation and technological growth has been and continues to be exponential. In particular, he posits that the pace of technological innovation is doubling every ten years (Kurzweil, 2001; Kurzweil, 2004).

Looking at some of the key technological innovations since the start of the industrial revolution, in particular starting with the creation of the printing press, to the steam engine, to electricity and creation of light bulb, it is clear that the pace of major innovations has been increasing at an ever phenomenal rate alongside the growth of the human population, and they continuously change the paradigm of human existence.

The printing press, created circa 1441 A.D., opened a broad gateway of communication never before possible in the mass publication of books and newspapers, and their widespread distribution. The printing press allowed mankind to share and distribute accumulated knowledge to a wider audience of the world population, and it encouraged a greater emphasis on and access to education (Febvre & Martin, 1997).

Increased knowledge, education, and distribution of information helped to bring about the harnessing of cheap energy via coal production, enabling the creation and viability of steam engines circa 1712 by Thomas Newcomen. The steam engine enabled multiple other innovations in manufacturing, metallurgy, mining, and transport (Rolt & Allen, 1977).

In the 1800's Thomas Edison perfected the light bulb, and therewith enabled artificial, sustainable, and inexpensive light to the utmost corners of the world (Frith & O'Brien, 2005).

In the early 1900's Henry Ford introduced the concept of mass production into the industrial community, transforming the workplace to allow greater productivity and efficiency than ever before seen (McCalley, 1994).

During World War II, with massive loss of life never before experienced in human history, the United States embarked upon what is today known as the Manhattan project. The top secret endeavor succeeded in the development of the first nuclear bomb that was later used on the nation of Japan, and precipitated a hastening to the end of this world conflict (Hewlett & Anderson, 1962). In addition, it established new ways of effectively managing large complex systems that since would be leveraged to successfully develop forthcoming systems of greater complexity in the 50's, 60's and on to present day.

In the 1950's, the Soviet Union successfully launched the first man into low earth orbit and returned him safely. This significant accomplishment by the Soviet Union led President John F. Kennedy to boldly declare that the U.S. would land a man on the moon, and return him safely to earth within the decade of the 1960's. The Apollo space program was the embodiment of that lofty goal, and by 1969 it culminated in the successful achievement of that goal (Reynolds, 2002).

As the cold war raged on silently in 1950's and 1960's, the U.S. embarked on the technological journey to create an aerodynamically sound, and undetectable aircraft capable of flying in extremely high altitudes to make it virtually impossible to shoot down. This program culminated in the creation of the SR-71 Blackbird (Graham, 2013).

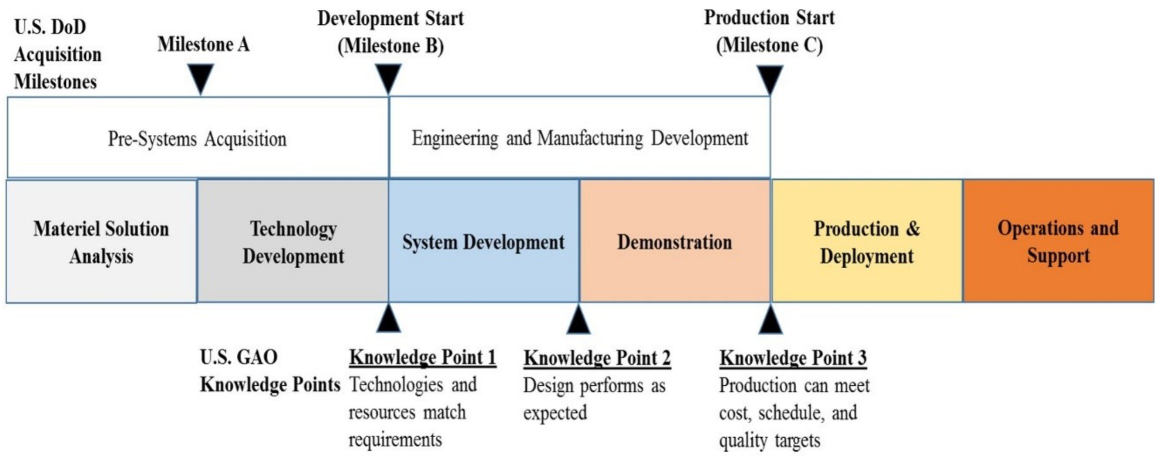
As the Apollo program was coming to an end in the early 1970's, the next step for NASA included the creation of a reusable spacecraft that could be launched into space orbit similar to a rocket, but after its mission could return to earth and land similar to an airplane. This program culminated in the Space Transport System (or more commonly referenced to as the Space Shuttle) (Coggon, 1984).

What is evident in all of the foregoing discussion is that concern for the readiness of the technology, let alone the obsolescence of said technology, was not a prominent consideration of the scientists and engineers of the time. The rate of change in technology was relatively slow for humankind, however with the advent of the industrial revolution, and in particular the birth of the computer/information age the rate of change has quickened so substantially that it is now relevant to humankind. Significant change in technology no longer takes generations to evolve, nor a lifetime, but a few years or less. With the increasing pace of technological advancement, has come the desire to discover and utilize these tools of innovation as early as possible in the development of the complex systems of today and the future. This in turn has led to the incorporation of immature technologies within many of the technologically complex systems comprising the U.S. DoD portfolio of major weapon systems which, as asserted by Meier (2010) and others, has led to cost and schedule increases, and decreases in delivery order quantities (DoQs).

3.3.1 Knowledge-Based Acquisition

In today's economic reality of tight budgets, with an ever increasing number of people from the baby boom generation leaving the workforce and entering retirement thereby reducing the tax base for the U.S. Government, while expecting and requiring an increased outlay of funds to support various social programs for the elderly (i.e. social security, Medicare, etc.), the U.S. DoD must find a way to operate with less, yet provide for the nation's defense in an increasingly hostile and dynamic world environment. The U.S. GAO has indicated a need for better management practices by the U.S. DoD to improve the performance outcomes of its weapon systems acquisitions (GAO, 1999). The U.S. Congress, in recognition of the mounting empirical evidence that incorporation of immature technology into the development cycle heightens the risk of cost and schedule growth, has mandated via the Weapon Systems Acquisition Reform Act of 2009 that all major defense acquisition programs (MDAPs) must have sufficiently mature critical technologies before they are allowed to proceed into the development phase (GAO, 1999; GAO, 2008b; Mandelbaum, 2009; Congress, 2009).

Separation of technology development from product development was recognized as a best practice by the U.S. GAO in a 1999 report on best practices (GAO, 1999). The report cited that "Leading commercial firms recognize a distinct difference between technology development and product development; accordingly, they develop technology before introducing it into product development programs. They minimize risk, improve cost and schedule outcomes, reduce cycle time, and improve quality during product development by gaining significant knowledge about a technology before launching the product development" (GAO, 1999, p. 13). Also in a 1998 study, U.S. GAO found that commercial companies "employ a disciplined process to match requirements with technological capability before the product development process begins" (GAO, 1998, p. 5). In an attempt to mirror these best practices from the commercial space within the military space, the U.S. GAO characterized the knowledge it felt was needed to realize successful new product development as three knowledge points (see Figure 3-2), where the achievement of each point is indicative of having attained "virtual certainty of some aspect of a product" (GAO, 1998, p. 22): 1) when the customer's requirements are in agreement with the currently available technology; 2) when the system's architecture and design are demonstrated to be viable in meeting the allocated performance requirements; and 3) when the producibility of the system is evaluated to be within the planned range for cost, schedule, and quality (GAO, 1998, p. 22; GAO, 1999).



Source: Adapted from 1999 U.S. GAO report

Figure 3-2. U.S. GAO Knowledge Points

Knowledge Point 1 aligns with Milestone B of the defense acquisition system (DAS) life cycle. It is indicative of when the critical technology to be used in a product development is sufficiently mature such that program technical risk is minimized. It includes the knowledge acquired from when prototypes of critical technologies have been developed and demonstrated in a relevant environment, at an affordable cost, reasonable schedule, and with expected performance (GAO, 1998; GAO, 1999).

Knowledge Point 2 aligns with the system level critical design review of the DAS life cycle. It is indicative of when the system design is stable, and the probability of meeting program requirements is high. It is reflective of increased knowledge from maturing engineering prototypes, as well as indicative that the design is ready for release to manufacturing (GAO, 1998; GAO, 1999).

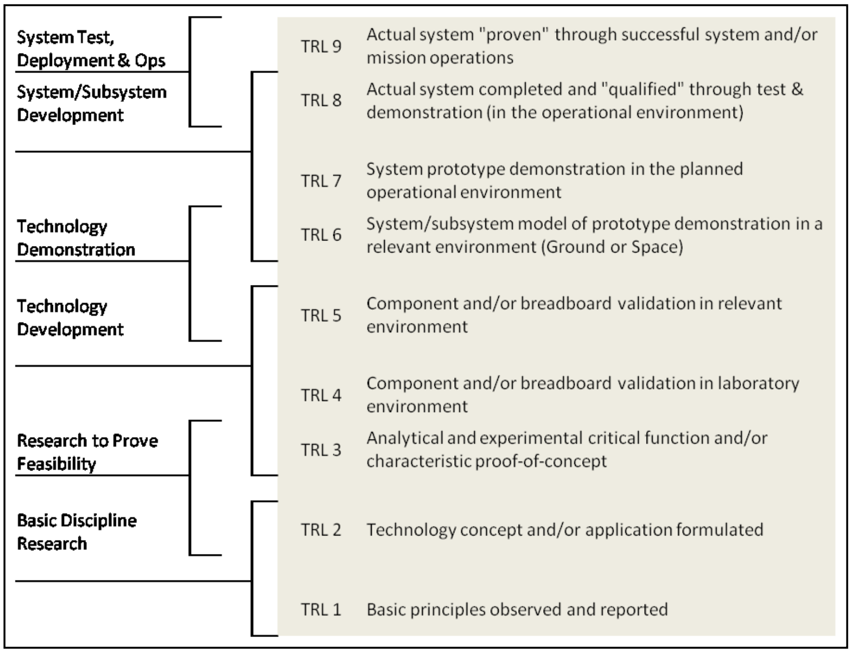
Knowledge Point 3 aligns with Milestone C and the start of the production process of the DAS life cycle. It is indicative of when all "critical manufacturing processes are…repeatable, sustainable, and capable of consistently producing parts within the products quality tolerances and standards" (GAO, 1998; GAO, 1999; GAO, 2009b). It is indicative of a complete engineering knowledge base reflective of technology that matches requirements, stability of design and demonstrable functionality in relevant and operational environments, and a high quality and reliable production process.

In 2003, the U.S. GAO started providing an annual report to the U.S. Congress of its assessment of a portfolio of selected major defense acquisition programs of the U.S. DoD, where alignment with best practices associated with knowledge-based acquisition approaches were key criteria. The report indicated that all the programs (26) that were assessed that year proceeded with less knowledge at critical junctures than best practices would have recommended (GAO, 2003). Consequently, it is no surprise that the majority of these programs were deficient in achieving their original cost, schedule, and performance expectations.

3.3.2 Key Tenets of Technology Readiness Assessments

So, what is a technology readiness assessment (TRA)? A technology readiness assessment is a systematic, metrics-based process that assesses the maturity and risks associated with critical technologies (CTs) to be used in MDAPs (DoD, 2011a). The results of a TRA is reflected in a metric referred as a technology readiness level (TRL). The original 7-level TRL scale was devised by Stanley Sadin during the late 1970s at NASA's Office of Aeronautics and Space Technology (OAST) as a means to assess technology maturity and provide a more consistent framework in which to compare technologies. By 1989, the 7-level TRL scale was formalized and later incorporated into NASA's Integrated Technology Plan (ITP) for civil space programs in 1991 (Sadin, Povinelli, & Rosen, 1989). In 1995, John C. Mankins extended the TRL scale into 9-levels and strengthened the definition of each TRL by adding better descriptions and practical examples (see Figure 3-3) (Mankins, 1995). In 1999, the U.S. GAO recommended adoption of the TRL scale by the U.S. DoD as a means to improve the quality and acquisition performance of their programs (GAO, 1999). This recommendation was endorsed by the Deputy Undersecretary of Defense for Science and Technology (DUSD S&T) in July 2001 as the tool of choice in assessing the technology maturity of MDAP critical components.

A TRA is conducted by the acquisition program manager. The results of the technology assessment is reported to the Assistant Secretary of Defense for Research and Engineering (ASD (R&E), and serves as part of the information that will be provided to the Milestone Decision Authority (MDA) at Milestone B. The MDA uses the TRA information to assist in determining the amount of technical risk associated with incorporating critical technologies into a program's E&MD development phase. An independent review team (IRT) assists the acquisition program manager with the process of identifying a few CTs believed to be the major drivers of cost and schedule performance over the entire acquisition life cycle. Then, each CT is assigned a TRL ranging from one to nine, with the goal of ensuring that each CT reaches TRL 6 prior to the E&MD phase (i.e., system/subsystem model or prototype demonstration in a relevant environment). In other words, large-scale system prototypes should demonstrate critical technologies that satisfy key performance requirements prior to detailed engineering design. Conversely, CTs that do not reach TRL 6 are considered principal drivers of acquisition performance risk and should be matured or removed from the weapon system design prior to E&MD (DoD, 2011a). Common CTs may be an advanced mission computer, fly-by-wire avionics system, low-observability coatings, fuel-efficient high-performance engines, etc. They are typically some advanced or leading-edge technologies that will push the performance envelope of the weapon system and thus provide a strategic military advantage (Petraeus, 2010).



Source: Adapted from Mankins expanded definition of TRLs

Figure 3-3. Technology Readiness Level Scale

3.3.3 Key Tenets of Technology Readiness Levels

As defined by Mankins (1995), the TRL scale has nine levels as depicted in Figure 3-3. These levels represent the range of technology development, from early observation of basic principles and conceptualization, through laboratory validation of breadboards, through demonstration of prototypes in a relevant environment, through operational system test and validation, to final successful mission operation. This evolution of technical maturity may be seen as growth through six overlapping development stages: 1) Basic Discipline Research, 2) Research to Prove Feasibility, 3) Technology Development, 4) Technology Demonstration, 5) System/Subsystem Development, 6) System Test, Deployment and Operations.

The Basic Discipline Research stage encompasses the transition of scientific research to applied research, to early conceptual development, innovation, and invention. It embodies TRL levels 1 and 2. The Research to Prove Feasibility stage actually overlaps some with the Basic Discipline Research in that it takes the conceptual framework and invention and starts to mature the concepts via detailed analytical studies and laboratory-based studies. These studies serve as proofs of concept of innovations advanced during TRL level 2. This stage embodies TRL levels 2, and 3. The Technology Development stage encompasses transition from early proofs of concept to experimentation within a laboratory of a breadboard of the conceptualized product. It includes maturing of a breadboard of the product such that its desired functionality is successfully demonstrated in a relevant environment. This stage embodies TRL levels 3, 4, and 5. The Technology Demonstration stage takes a breadboard prototype and transitions it into an integrated system prototype and again demonstrates the desired functionality within a relevant environment. This stage embodies TRL levels 5 and 6. The System/Subsystem Development stage encompasses the transition of the technology from an integrated system prototype being tested in a relevant environment, to an integrated system prototype being tested in a controlled operational environment, to an integrated system being tested in an operational environment. This stage embodies TRL levels 6, 7, and 8. The System Test, Deployment and Operations stage is the final step in the technology maturation process. It transitions the newly innovated integrated system into full usage and mission operations. The stage embodies TRL levels 8 and 9. (Mankins, 1995; Mankins, 2009a)

Today, there have been many attempts to duplicate or leverage the value of TRLs with tailored readiness scales for hardware, software, manufacturing, medical devices, nuclear energy, pharmaceuticals, petrochemicals, etc. TRLs have even been expanded into manufacturing readiness levels (MRLs), integration readiness levels (IRLs), and system readiness levels (SRLs) to evaluate the maturity of interfaces between individual technologies (Cundiff, 2003; Sauser, Verma, Ramirez-Marquez, & Gove, 2006). Others, such as Clausing & Holmes (2010), have devised structured technology readiness methods which add quantification measures like failure modes, critical parameters, and latitude in attempts to remove perceived subjectivity within NASA's TRL framework. Valerdi & Kohl (2004) described the benefit of TRLs in supporting the management of technology risk, and devised an enhancement to the TRL metric that would incorporate consideration of some of the negative aspects of immaturity such as technology obsolescence. Likewise, Smith II (2005), proposed a method to enhance the TRL metric with critical factors (e.g. aging, environment, requirements) to provide a more accurate assessment for non-developmental item (NDI) software items. Mankins (2009b) advocated a new management tool that combined three figures of merit (FOM): technology readiness level (TRL), research and development design difficulty (R&D3), and technology need value (TNV) to formulate a technology readiness and risk assessment (TRRA) measure of a technology or system under development. Dubos et al. (2007) discussed the relationship between technology uncertainty and schedule risk in the acquisition of space systems, and proposed an analytical framework to identify appropriate schedule margins for mitigating the risk of schedule slippage that included the development of a set of schedule risk curves that could be used to help decision makers manage the risk to their programs based upon the schedule margin incorporated and the TRL assessment of the system at startup. However, the U.S. DoD and U.S. GAO continue to support the use of its TRA process and its 9-level TRL scale (DoD, 2007, 2008, & 2011a), in lieu of the newer mathematical techniques such as SRLs which only provide incremental gains (Kujawski, 2013; McConkie, Mazzuchi, Sarkani, & Marchette, 2012).

U.S. DoD decision makers believe that cost and schedule performance is a direct result of what is known as technology maturity, which is a metric that reflects the readiness of critical technologies to be used to meet program objectives (DoD, 2006). The U.S. DoD addresses technology maturity in two broad sweeping and highly-interrelated approaches. The first is the defense acquisition lifecycle itself (see Figure 3-2), which is a five-stage process: (a) materiel solution analysis or MSA, (b) technology development or TD, (c) engineering and manufacturing development or E&MD (comprised of System Development and Demonstration activities), (d) production and deployment or P&D, and (e) operations and support or O&S (DAU, 2010). In this approach, it is believed that programs can reduce cost and schedule overruns with sufficient investments in basic research and development (R&D) and the construction of large-scale proofs of concept or system prototypes prior to detailed engineering design. Therefore, the U.S. DoD believes that most downstream errors are attributable to management and engineering effort committed in the early acquisition stages or lack of sufficient upstream investments in systems engineering activities at these early stages (DoD, 2008).

The second approach, which complements the first, is the practice of conducting Technology Readiness Assessments (TRAs) in these early stages. The U.S. DoD believes that critical technologies (CTs) should be identified during the TD phase, modeled within large-scale system prototypes, and measured using the technology readiness level (TRL). Critical technologies are "those that may pose major technological risk during development, particularly during the Engineering and Manufacturing Development (E&MD) phase of acquisition" (DoD, 2011a, p. 1-1). The U.S. DoD wants to ensure that suppliers aren't incorporating vaporware into their weapon system designs that will later cause cost and schedule delays in order to move these ideas beyond the creative imaginations of research scientists. The U.S. DoD would rather have proven technologies that offer moderate performance improvement, and are well beyond the idea stages, in order to meet scope, cost, schedule, and performance constraints. However, to-date the basic arguments in favor of applying the five-stage U.S. DoD acquisition life cycle, upfront investments in large-scale system prototypes during the TD phase, and the performance of TRAs, along with identifying its associated CTs, assigning TRLs, and ensuring they reach TRL 6, are mostly qualitative.

For example, Kenley & El-Khoury (2012, p. 221) in an analysis of TRL based cost and schedule models developed a theoretical framework comprised of 4 levels of assumptions: "1) TRL scale is measure of maturity and risk, 2) Transition maturity variables <(e.g. schedule to transition between TRL 5-6)> are consistently related across technologies, 3) Maturity variables <(e.g. cost, schedule, performance, risk)> are significantly different for different technologies, 4) TRL marks points of progression in technology development". The authors posited that the TRL could be mapped to the level of uncertainty regarding cost, schedule, and technical performance. Furthermore, they deduced the existence of an inverse relationship between TRL level and cost, schedule, and performance, stating that as the TRL level progressed, cost, schedule, and technical performance uncertainty would decrease. Similar research by Guo et al. (2011), and Dubos et al. (2007) posited that a lower TRL would lead to higher program technology risk, and therefore higher probability of cost overrun. Studies such as these are starting to emerge and provide additional, mostly qualitative, insight into the benefits of TRL usage. However, little quantitative evidence has been collected to-date on the actual economic benefits of technology maturity via TRAs. Therefore, the purpose of this study is to examine the recent slew of acquisition performance data emerging from government agencies such as the U.S. GAO, as well as other sources, and apply economic models to begin examining the quantitative benefits of technology maturity. The results of this analysis should help U.S. DoD decision makers, acquisition program managers, systems engineers, and researchers determine whether acquisition best practices have a positive effect on acquisition outcomes. More importantly, such evidence would also be interesting to military strategists, if the use of TRAs help reduce cost and schedule overruns and increase DoQs (Petraeus, 2010).

3.4 History of Quantification Methods of Economic Value

Acquisition performance continues to suffer from excessive cost and schedule overruns, reduced DoQs, and some are cancelled outright. The U.S. DoD believes that technology maturity, or lack thereof, is a primary measure of acquisition performance (GAO, 2008b). That is, weapon systems that use mature technologies will have better acquisition performance than those using immature technologies (Meier, 2008). Technical maturity or knowledge-based practices as they're frequently called, such as the TD phase, full-scale system prototype, and TRA process together cost up to 10% of the acquisition expenses through the manufacturing phase. The fundamental theory is that these upfront technology maturity investments will head off downstream manufacturing, operating, and maintenance costs (DoD, 2006; DoD, 2008). However, most of these costs are incurred based on the face validity of the TRA process itself (i.e., they're taken on faith). Little data and information are actually available on the actual economic or hard-benefits of performing TRAs. Even those whom may be considered ardent supporters of TRAs want to quantify their economic benefits (Dubos, Saleh, & Braun, 2007; Kenley & El-Khoury, 2012). Although economic valuation is a rather dated practice and many people now believe that qualitative or intangible benefits are of paramount importance, the use of economic valuation is experiencing a revival of sorts throughout the project management, engineering, information technology, and acquisition communities (Honour, 2004; Reinertsen, 2009). Among these, the most commonly cited measure of business value is the concept of return on investment or ROI (Morgan, 2005).

What is return on investment? There are several interpretations. Businesses may view it as the gain in profits or market leverage to which the acquired technology will contribute (Coyle, 2006). The U.S. GAO describes ROI as "cost savings to acquisition programs, reduced times for completing testing and evaluation and integrating technologies into programs, and/or enhanced performance or new capabilities" (GAO, 2005b, p. 21). Why is ROI important? It provides a quantitative measure to the decision maker from which to aid in the selection of a course of action. The ROI metric has been proven to be extremely valuable in helping to characterize an investment or course of action in financial terms, specifically costs and benefits, which are relevant to the business enterprise. The quantification of ROI, however, is difficult within the U.S. DoD context as compared to commercial enterprise, since the end objective is not profit, but success of mission, minimization of lives lost, and force effectiveness (Oswalt, 2011).

Developing a program guided by the concept of TRAs can seem resource costly and time consuming early on in acquisition cycle. "Preparation for a TRA requires acquisition programs to perform the necessary engineering work as defined by U.S. DoD acquisition guidance in order to mature technologies incrementally" and sufficiently (Azizian, Mazzuchi, Sarkani, & Rico, 2011a, p. 413). In order to ensure a business mindset was utilized within the government's acquisition practices the U.S. Congress via the Clinger-Cohen Act of 1996 requires each executive agency to implement a process of maximizing the value and assessing and managing the risks of its information technology (IT) acquisitions. This includes establishing minimum criteria to be applied in consideration of IT investments such as criteria related to a quantitatively expressed projected net, risk-adjusted ROI, and other criteria (Congress, 1996). The U.S. DoD in 2005 issued DoD Directive 8115.01, which instructed each of the military services to manage their IT investments as portfolios to maximize ROI to the Enterprise, versus managing and acquiring systems in a standalone fashion rather than as an integral component of a net-centric capability (DoD, 2005). In a 2007 report, the U.S. GAO recommended to the U.S. DoD to implement an integrated portfolio management approach to weapon systems investments to maximize ROI (GAO, 2007b).

It is clear the U.S. Congress, U.S. DoD, and U.S. GAO desire to bring a more heightened business mindset to the acquisition process of IT and products to help ensure budget allocations are managed as prudently as possible. Having a relevant performance measure such as ROI is a valuable tool to gain critical insight into the business value of an investment, and useful in comparing the merits of a portfolio of investments.

However, there are some problems associated with ROI. First of all, some may attribute morale, trust, customer satisfaction, communication quality, collaboration, and other soft, non-quantitative measures to ROI. A smaller percentage of professionals may be aware of the mathematical or economic form of ROI. That is, cumulative economic benefits less costs, divided by costs. Contemporary economists feel the quantitative form of ROI is an unrealistic and perhaps obsolete measure of economic performance due to its lack of consideration of the time value of money (Kodukula & Papudesu, 2006; Dixit & Pindyck, 1995). Therefore, economists promote other, more valid measures, such as net present value (NPV), internal rate of return (IRR), real options analysis (ROA), and numerous other measures of project performance (Tockey, 2004). Today, there are hundreds of economic models from which to choose and their numbers are growing every day. It's interesting to note that most of these methods are what is known as top-down parametric models, which require only a few basic inputs, such as costs, benefits, interest rate, time horizon, or even risk. The key inputs, of course, are costs and benefits. Cost data is being collected in increasing frequency and soft or non-quantitative benefits are sometimes collected as well. It's only when the latter are converted into economic terms or monetized, that the plethora, suite, or portfolio of economic equations and models may be applied. In spite of the myriad of complex economic methods, three basic forms seem to be standing the test of time (i.e., B/CR, ROI%, and NPV). Both B/CR and ROI% may be considered too optimistic because they do not incorporate the time value of money, and NPV may be considered too pessimistic because it does not consider the financial potential of managerial risk taking. A relatively new economic model, ROA often mirrors B/CR and ROI%, because it adds value back to the sum due to the presence of risk and its estimation curve isn't quite so steep.

What is NPV? It is one of many discounted cash flow (DCF) methods that has emerged in an attempt to provide a more accurate estimate of potential ROI of a project than the traditional ROI valuation method. The net present value (NPV) method provides an approach to estimate the value of a project over it entire life time. It attempts to account for the delta between the present value of investment costs and the present value of the production free cash flow associated with a project (Kodukula & Papudesu, 2006). According to Mian (2011, p. 313), "When NPV of an investment at a certain discount rate is positive, it pays for the cost of financing the investment or the cost of the alternative use of funds…Conversely, a negative NPV indicates the investment is not generating earnings equivalent to those expected from the alternative use of funds, thus causing opportunity loss." Part of its distinction from the traditional ROI method, is that it includes consideration for the time cost of money. The NPV method has been used for many years to assist business leaders in choosing between alternative business opportunities.

What is ROA? In the 1970's economists Fischer Black and Myron Scholes, along with later contributions by Robert Merton, provided a breakthrough in option pricing that revolutionized the financial options field. They provided a rather simple differential equation to calculate the value of a European style option, named after its authors, the "Black & Scholes" method (Black & Scholes, 1973; Merton, 1973). The Nobel Prize in Economics was awarded to them in 1997 for this achievement and its impact upon the financial world. Their approach provides a pragmatic way of incorporating projected future uncertainty (or risk) into the valuation of a financial investment. A detailed discussion and proof of this method is not the focus of this study, and is left to the reader.

Real options analysis evolved from the financial formulation of the Black & Scholes method to that similarly represented by (Kodukula & Papudesu, 2006) to address non-financial asset option valuation. (See Figure 3-4.) The formula provides the valuation of a non-financial asset at some time "T" in the future, as:

$C = N(d_1)S_0 - N(d_2)X \exp^{(-rT)}$
- C = value of the call option - S_0 = current value of the underlying asset - X = cost of investment or strike price - r = risk-free rate of return - T = time to expiration - $N(d_1)$, $N(d_2)$ = standard normal distribution values at d_1 and d_2 - $d_1 = [\ln (S_0/X) + (r + 0.5\sigma^2)T]/ \sigma\sqrt{T}$, $d_2 = d_1 - \sigma\sqrt{T}$ - σ = volatility factor, or uncertainty of underlying asset value

Source: adapted from Kodukula and Papudesu "Project Valuation Using Real Options

Figure 3-4. Real Options Formulation (Black & Scholes method)

Given the data for these parameters, the option value of the non-financial asset may be calculated quite readily. The difficulty within each domain has been obtaining the data behind the parameters. The volatility factor, σ, represents the uncertainty of the underlying asset value, and may be considered the most difficult to ascertain due to the fact there is generally no historical information regarding the underlying asset value (Kodukula & Papudesu, 2006).

What are options? Options may be classified into two broad categories: financial or real, depending upon whether the underlying asset is a financial or real asset. Financial assets are primarily stocks and bonds traded on financial markets. Real assets are real estate, projects, intellectual property, etc., that are not normally traded. A financial option provides the right, but not the obligation, to take an action (that is to buy or sell) on an underlying financial asset at a predetermined price on or before a predetermined date. A real option provides the right, but not the obligation, to take action (that is to defer, expand, contract, invest, abandon, etc.) on an underlying non-financial asset at a predetermined cost on or before a predetermined date.

Options can be evaluated as either European or American. European style options may be exercised only upon arrival of a fixed date. American style options may be exercised anytime up to a given fixed date. In the literature, both styles have similar characteristics, and consequently share much of the same terminology. Our study utilizes European style valuation.

Trigeorgis (2005) asserted that insight gained from viewing investment opportunities through a real options lens can be very powerful. It provides flexibility to the management decision process that was not present with traditional option valuation techniques. In the face of high uncertainty, the flexibility to delay a decision or full commitment until such time as sufficient information is acquired can be highly valuable. Schwartz & Gorostiza (2003) further asserted that evaluation tools traditionally used on projects, such as NPV or IRR, are inadequate for coping with the high uncertainties for which IT projects are typically encumbered. Shishko, Ebbeler, & Fox (2004) discussed that the insights gained by management through real options may be used to help prioritize investments, and proposed a framework to leverage the insights obtained via real options in support of NASA's advanced technology decision process, in particular highlighting development and programmatic risk. Gray et al. (2005) proposed utilizing real options frameworks as a new way of thinking that offers benefits to the complex process of mission design, in particular how to value and architect flexibility in the guise of technical uncertainty. Mun & Housel (2006) provide a comprehensive discussion on modern tools that may assist the decision making process, including use of real option analysis, within the context of the U.S. DoD. Mun et al. asserted that these new tools, real options, Monte Carlo simulation, portfolio optimization, etc., are enablers of a new approach of estimating ROI and risk-value of various strategic real options.

Literature on the use of real options analysis, although a relatively new tool, is a growing area of research in many technical and management domains. However, there is minimal research into real options valuation of TRAs, in particular associated with MDAPs.

3.5 Gaps in the Literature

Although TRAs have been in existence for over 40 years, and literally thousands of technology assessments performed during that time, the current literature essentially is void of any scientific investigation into the economic benefits associated with TRAs and knowledge-based engineering practices. What is the relationship between B/CR of TRAs and acquisition performance? What is the relationship between NPV of TRAs and acquisition performance? What is the relationship between ROA of TRAs and acquisition performance? This study is an initial attempt to address these knowledge gaps.

4 Research Framework

4.1 Summary of Framework

The purpose of this chapter is to present a process framework for analyzing the value of TRAs among U.S. DoD acquisitions. As shown in Figure 4-1, the process framework consists of four broad stages or phases: (a) analyze costs of TRAs, (b) analyze risks of TRAs, (c) analyze benefits of TRAs, and (d) analyze value of TRAs. The process framework is based upon commonly accepted standards, methods, and guidelines for evaluating the costs and benefits of acquisition, program, and project data (Mian, 2011; Newnan, Eschenbach, & Lavelle, 2011; Sullivan, Wicks, & Koelling, 2011). Basic valuation methods such as ROI necessitate cost and benefit data as inputs. However, advanced economic valuation methods require the use of risk as an input. It's important to note that these basic inputs, costs, benefits, and risks, are rarely available for valuation purposes. In recent years, all three of these basic inputs have become more available, making it possible to combine these basic analyses into a comprehensive process framework. More importantly, as in the case of ROA, simple, top-down parametric forms of these equations have recently become available, in lieu of advanced mathematical equations, lengthy heuristics, or voluminous narratives, with little practical value (Kodukula & Papudesu, 2006). In a real sense, it is the combination of publicly available acquisition data, along with the emergence of simple parametrics, which directly led to the formation of our process framework.

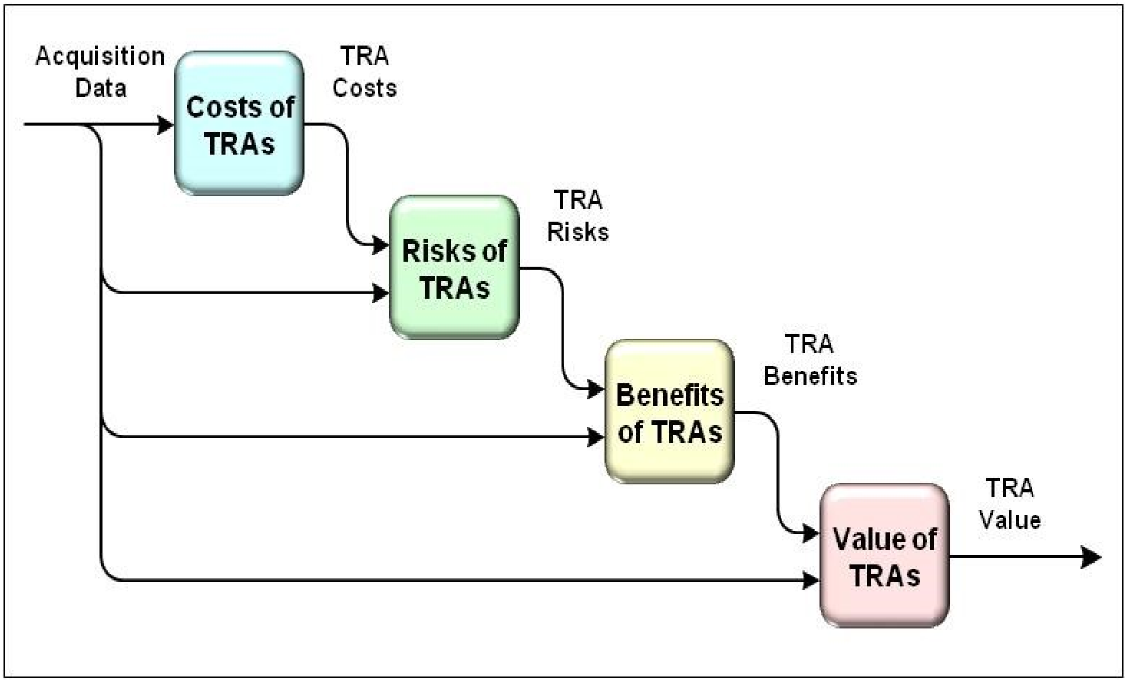


Figure 4-1. Framework for Analyzing the Value of Technology Readiness Assessments

4.2 Costs of TRAs

This process or stage consists of analyzing several levels of acquisition-related costs. These include R&D costs, technology development costs, technology readiness costs, and total acquisition costs. R&D costs typically entail costs ranging from conceptual analysis through the completion of a full-scale system prototype. Technology development costs typically include the costs of developing the prototype itself. TRA costs average about 1.5% of the cost of the TD phase. Total acquisition costs include the entire set of costs accumulated to-date.

4.3 Risks of TRAs

This process or stage consists of analyzing several levels of acquisition-related risks. This primarily includes the technology maturity-related risks. That is, the costs associated with low and high maturity. For instance, acquisitions with low technology maturity have consistently exhibited poor cost and schedule performance (Guo, Li, & Ou, 2011). Low maturity may also be associated with reduced DoQs. Another major form of risk is the sheer weight of the total acquisition in terms of its complexity and associated costs. That is, acquisitions with higher costs generally reflect some sort of increased complexity. Simpler acquisitions have lower costs, thus representing lower cost risk, while more complex acquisitions have higher costs, and higher cost risks. Boehm (2008), upon analysis of 161 software projects, emphasized the benefit of early architecture and risk resolution in reducing rework and its associated impact to cost and schedule. Therefore, both technology as well as total acquisition cost will be used to compute a composite risk index.

4.4 Benefits of TRAs

This process or stage consists of analyzing several levels of acquisition benefits. These may include cost, schedule, and technical related performance. That is, better performing acquisitions have better cost, schedule, and technical performance. Conversely, poor performing acquisitions have worse performance. The U.S. DoD has attributed the acquisition performance to many factors over the years, such as acquisition, program management, and systems engineering discipline, or the lack thereof. Over the last decade, the U.S. DoD has focused more and more on the contribution of technology maturity to acquisition performance. That is, it is believed that high technology maturity leads to better acquisition performance (DoD, 2011a). Therefore, the contribution of technology maturity to acquisition performance will be analyzed.

4.5 Value of TRAs

This process or stage consists of analyzing several levels of acquisition value using basic inputs such as costs, risks, and benefits (Rico, 2005). These include benefit to cost ratio (B/CR), return on investment percentage (ROI%), net present value (NPV), breakeven point (BEP), and even real options analysis (ROA). B/CR and ROI% are simple ratios of benefits to costs, NPV considers the time value of money, BEP reflects the point at which the accumulated benefits have equaled the investment costs, and ROA considers the benefits of risk. That is, risk may be an important driver of business value when it is spread over time. This is done at several levels and in increasing frequency in U.S. DoD acquisitions (DoD, 2008). At its most basic level, U.S. DoD acquisitions are divided into five stages (i.e., MSA, TD, E&MD, P&D, and O&S). Then, each is further divided into four increments for a total of 16 stages. Now that lean and agile methods are common, these stages are divided into 64 stages (Duvall, 2012). These stages divide the total acquisition scope into smaller batches, spread the risk over time, increase learning when it is least expensive to do so, and decrease the impact of downstream costs due to system acquisition risks. Therefore, ROA may be a good technique for analyzing the economic value of U.S. DoD acquisitions (Dixit & Pindyck, 1995).

5 Research Methodology

5.1 Summary of Methodology

The purpose of this chapter is to present the return on investment (ROI) methodology used in this research to collect, assess, and evaluate measurements used to characterize the economic value of TRAs. The steps involved with this methodology are highlighted in Figure 5-1. The methodology was comprised of three major components: 1) operationalization of the ROI of TRA Model, 2) the collection of associated data, and 3) the initial analysis of the data. The operationalization of the ROI of TRA Model component was further decomposed into eight steps: 1) estimation of the cost of implementing TRAs and knowledge-based practices, 2) estimation of the benefit (or amount saved) due to implementation of TRAs and knowledge-based practices, 3) estimation of the benefit/cost ratio due to implementation of TRAs and knowledge-based practices, 4) estimation of the return on investment percentage (ROI%) due to implementation of TRAs and knowledge-based practices, 5) estimation of net present value of ROI due to implementation of TRAs and knowledge-based practices, 6) estimation of breakeven point (BEP) due to implementation of TRAs and knowledge-based practices, 7) estimation of cost and technical risk due to the maturity of critical technologies, and 8) an estimation of real option analysis valuation due to implementation of TRAs and knowledge-based practices.

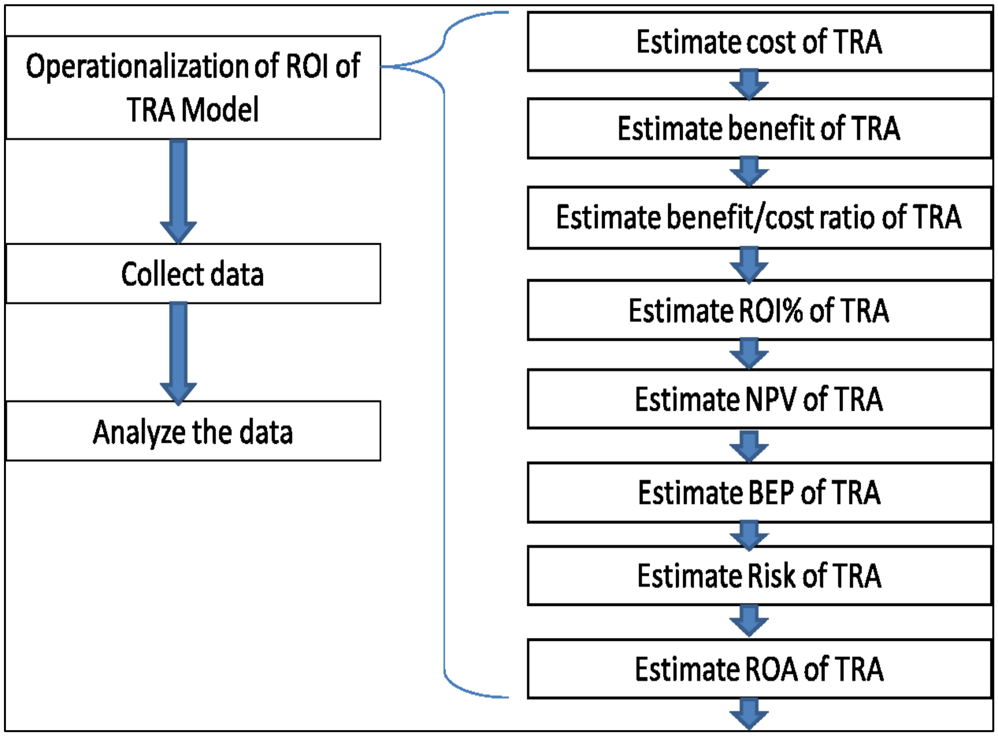


Figure 5-1. ROI of TRA Methodology Process

The methodology was used to help determine the costs and benefits of technology maturity and whether it is related to improved acquisition performance (see Table 5-1). These metric formulations were advanced by Rico (2007), and based upon economic measures discussed by Mian (2011).

Table 5-1. A suite of simple metrics for analyzing the value of TRAs

Costs	Total amount of money spent on technology readiness	$\sum_{i=1}^{n} Cost_i$
Benefits	Total amount of money gained from technology readiness	$\sum_{i=1}^{n} Benefit_i$
B/CR	Ratio of technology readiness benefits to costs	$\frac{Benefits}{Costs}$
ROI%	Ratio of adjusted technology readiness benefits to costs	$\frac{Benefits - Costs}{Costs} \times 100\%$
NPV	Discounted cash flows of technology readiness	$\sum_{i=1}^{Years} \frac{Benefits_i}{(1+DiscountRate)^{Years}} - Costs$
BEP	Point when benefits exceed costs of technology readiness (normalized to years)	$\frac{Costs}{NPV} \times Years$
ROA	Business value realized from strategic delay due to risk	$N(d_1) \times Benefits - N(d_2) \times Costs \times e^{-Rate \times Years}$

Years represents investment timeframe; $N(d_1)$ and $N(d_2)$ are standard normal distribution functions, where

$d1 = [\ln(Benefits \div Costs) + (Rate + 0.5 \times Risk^2) \times Years] \div Risk \times \sqrt{Years}$, $d2 = d1 - Risk \times \sqrt{Years}$

Source: Rico (2007).

These 7 metrics provide the basis for analysis of the ROI for TRAs used in this study. They align with the Black & Scholes formula described earlier: $C = N(d_1)S_0 - N(d_2)X \exp^{(-rT)}$, and are discussed in more detail in the sections which follow. For the primary analysis in this study a discount interest rate of 5%, and an investment period of 5 years was assumed. The risk variable is allowed to float based upon the technology maturity composite risk. In the latter stages of the analysis these baseline values were adjusted to assess the sensitivity of the model to changes in rate and/or investment period.

To accomplish the goals of this study, a spreadsheet model was developed and utilized. Ample sources of data were provided by U.S. GAO annual reports on the portfolio of major defense acquisition programs (MDAPs) for the 2003 to 2012 timeframe. For selected MDAPs these reports provided detailed analysis information in a two-page format that included an assessment of technology maturity, and a summary of cost and schedule metrics (see Appendix A.). The data was used to populate this study's spreadsheet database. The number of MDAPs per year studied in these reports ranged from 26 to 72. Where sufficient data was not provided for a particular MDAP, it was excluded from the study. (See Table 5-2).

Table 5-2. Number of MDAPs included in this study

Year	Total Programs Assessed in U.S. GAO Report	Number Programs with Detailed 2-page Summary Assessments	Number Selected for Study
2012	68	48	47
2011	71	49	49
2010	70	57	55
2009	67	60	59
2008	72	72	72
2007	62	62	62
2006	52	52	51
2005	54	54	54
2004	51	51	51
2003	26	26	26

Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012.

The spreadsheet model was constructed consisting of basic attributes, such as government agency, program type, program name, acquisition costs, and technology maturity. Then, other fundamental valuation drivers were added to derive key indicators of value, such as acquisition risks, TRA costs, and TRA benefits. Using the basic acquisition attributes and derived data, metrics and models were then added to help determine the value of TRAs. These included benefit/cost ratio (B/CR), return on investment (ROI) percentage, net present value (NPV), breakeven point (BEP), and real options analysis (ROA) methods. The cost and benefit spreadsheet was then populated with acquisition data from U.S. GAO Selected Acquisition Reports (SARs) covering the 10 year period from 2003 to 2012 for further analysis.

5.2 Costs of TRAs Model

The cost model for the TRA process reflects a procedure to collect, assess, and evaluate the amount of money spent on executing the TRA process and associated knowledge-based practices. The costs of TRAs represents the economic consequence of using TRAs and associated knowledge-based practices to identify and mitigate technology risk early in the program life cycle. The cost model for the TRA process encompasses the activities defined within DoDI 5000.02, and consists of training, preparation and execution of the assessment process, selection and utilization of an independent review team, and execution of knowledge-based practices, including prototyping of critical technologies (CTs) early (DoD, 2008). The cost model is reflected as follows, and within this study is estimated at 10 percent of the total program cost:

- Cost = TRA cost + TRA knowledge-based practices

5.3 Benefits of TRAs Model

The benefits model for the TRA process reflects a procedure to collect, assess, and evaluate the amount of money returned (or saved) for executing the TRA process and associated knowledge-based practices. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). The benefit of TRAs model represents the economic value of using the TRA process and knowledge-based practices to identify and mitigate technology risk early in the program life cycle. The key components of this measure includes an estimation of the total life cycle cost of TRAs and knowledge-based practices, and an estimate of the total benefit (savings) that includes an estimation of reduced defects, rework, integration and test. The benefits metric used in this study is the estimated monetization of the efficiency gained (or money saved) due to use of TRA knowledge-based practices when compared to the average cost overages experienced by programs that begin development with immature technology (de Weck, de Neufville, & Chaize, 2004). The benefits metric is based upon several U.S. GAO reports generated over the last decade that have indicated a cost benefit of at least 29.7% of total program cost for those programs that sufficiently matured their critical technologies before starting development (GAO, 2006; GAO, 2007a; GAO, 2008a; GAO, 2011). The benefits model is reflected as follows:

- Benefits = (Total program cost – Risk adjusted Cost) * Benefit constant

5.4 Benefit/Cost Ratio of TRAs Model

The benefit/cost ratio (B/CR) model for the TRA process reflects a procedure to collect, assess, and evaluate the ratio of benefits to costs for executing the TRA process and associated knowledge-based practices. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). The B/CR of TRAs model represents the economic significance of using the TRA process and knowledge-based practices to identify and mitigate technology risk early in the program life cycle. The key components of this measure includes an estimation of the total life cycle cost of TRAs and knowledge-based practices, and an estimate of the total benefit (savings) that includes estimation of reduced defects, rework, integration and test. The benefit/cost ratio (B/CR) provides a quantitative measure of the ratio of benefits to costs of TRAs. It provides the economic magnitude of using TRA knowledge-based practices to ensure appropriately matured technology is incorporated into a development program. Whereas a commercial corporation seeks to maximize profit and market share, the U.S. DoD does not have a profit motive, but rather the achievement of mission objectives within cost, schedule and technical parameters targeted. Its goal is to be the preeminent defender and protector of the nation, while simultaneously being good stewards of the public trust by maximizing the return on its investments into military weapon systems and services (Congress, 1996). The B/CR model is reflected as follows:

- B/CR = Benefit / TRA cost

5.5 Return on Investment Percentage of TRAs Model

The return on investment percentage (ROI%) model for the TRA process reflects a procedure to collect, assess, and evaluate the money returned (saved) for executing the TRA process and associated knowledge-based practices. ROI% represents the ratio of net benefits to costs. It reflects the money earned (saved) from using the TRA process. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). The ROI% of TRAs model represents the economic significance of using the TRA process and knowledge-based practices to identify and mitigate technology risk early in the program life cycle. The key components of this measure includes subtracting the estimation of the total life cycle cost of TRAs and knowledge-based practices from the gross benefits to compute net benefits. Note, the formulations for B/CR and ROI% are quite similar, comparing benefits to costs. The difference is that B/CR uses gross benefits, while ROI% uses net benefits, without including the cost of implementation. ROI% reflects a lower significance of benefits to costs than does B/CR. This difference shown by ROI% helps to form a more accurate and realistic picture of the actual benefits of using the TRA process and knowledge-based practices. The ROI% model is reflected as follows:

- ROI% = (Benefit – TRA cost)/TRA cost * 100%

5.6 Net Present Value of TRAs Model

The net present value (NPV) model for the TRA process reflects a procedure to collect, assess, and evaluate the money returned (saved) less inflation for executing the TRA process and associated knowledge-based practices. It reflects the discounted money earned (saved) from using the TRA process and knowledge-based practices. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). The NPV of TRAs model represents the economic value of using the TRA process and knowledge-based practices to identify and mitigate technology risk early in the program life cycle. The key components of this measure includes combining discounted net benefits with TRA costs via the B/CR formulation. Note, the formulations for B/CR, ROI%, and NPV are quite similar, comparing benefits to costs. The difference is that B/CR uses gross benefits to objectively analyze costs, while ROI% uses net benefits, without including the cost of implementation to avoid overstating the benefits, and NPV adjusts for inflation to provide a more conservative estimation of the significance of the benefits to the costs. NPV reflects a lower significance of benefits to costs than does B/CR, or ROI%. This difference shown by NPV helps to form a more accurate and realistic picture of the actual benefits of using the TRA process and knowledge-based practices. The NPV model is reflected as follows:

- NPV = Benefits/(1+Discount Rate)$^{\text{Years}}$ – TRA cost

5.7 Breakeven Point of TRAs Model

The breakeven point (BEP) model for the TRA process reflects a procedure to collect, assess, and evaluate when benefits exceed costs for executing the TRA process and associated knowledge-based practices. It reflects the value at which the benefits overtake the costs for utilizing the TRA process and knowledge-based practices. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). The BEP of TRAs model represents the point in the program life cycle that the benefit of using the TRA process and knowledge-based practices to identify and mitigate technology risk early in the program life cycle exceeds the associated costs. The key components of this measure includes combining TRA costs with the productivity gains achieved via the TRA process and knowledge-based practices. When utilized with one or more of the other ROI measures already described herein, this metric provides valuable insight to the decision maker. The BEP model is reflected as follows:

- BEP = (TRA cost/NPV) * Years

Note, this formulation of the BEP is intended to represent the metric in units of years.

5.8 Risk of TRAs Model

The risk model for the TRA process reflects a procedure to collect, assess, and evaluate the programmatic risk associated with immature critical technologies (CTs) being incorporated into a development program. It reflects the relative U.S. DoD portfolio risks, both cost and technical, for utilizing the TRA process and knowledge-based practices. The model combines cost risk, with technology risk, to determine an overall risk percentage within a portfolio.

- Cost risk = ranking of total costs
- Technology risk = ranking of technology maturity
- Combined risk = composite of cost and moderated technology risk
- Risk = overall ranking of combined risk

5.9 Real Options Analysis of TRAs Model

The real options analysis (ROA) model for the TRA process reflects a procedure to collect, assess, and evaluate the money returned (saved) less inflation, while also incorporating the added value of flexibility to alter course depending upon business risk conditions. It reflects the value earned (saved) by waiting until critical technologies (CTs) are sufficiently mature before being incorporated into a product development. The TRA process and knowledge-based practices mitigates the risk of including insufficiently mature technologies into the E&MD phase of the program life cycle, thereby helping to minimize cost and schedule overruns, and reductions in DoQs (Meier, 2010). Literature highlights three approaches that are mostly used in calculating real option values: (a) Black-Scholes method, i.e., partial differential equation given in Table 5-1, (b) simulation, e.g. Monte Carlo, and (c) lattices (Black & Scholes, 1973; Kodukula & Papudesu, 2006; Wang & de Neufville, 2005). Each approach has its advantages and disadvantages. Each approach provides insight not available via traditional business valuation techniques such as discounted cash flow (DCF), or NPV. DCF and NPV typically undervalue actual assets or project benefits because they assume project managers have no flexibility in the decisions made for guiding the project (Neely III & de Neufville, 2001; Wang & de Neufville, 2005). In reality, most project managers have flexibility to change direction of a project as new data and information emerge to help remove uncertainty about the viability of a chosen or desired path (de Weck, de Neufville, & Chaize, 2004). ROA attempts to estimate the value of this flexibility. Trigeorgis (1993) asserts managerial flexibility is a set of real options which may consist of options to defer, abandon, contract, expand, or switch investment. Each of these options may result in a different valuation. This study utilizes the Black-Scholes method for determining real option value as it provides the most accurate valuation of the three approaches. As suggested earlier, parametric forms of ROA have emerged making it possible to analyze acquisition performance (Kodukula & Papudesu, 2006). The Black & Scholes model is reflected as follows:

- ROA = $N(d_1)$*Benefits-$N(d_2)$*Cost*$e^{-\text{Rate}*\text{Years}}$, where
- d_1 = [ln (Benefits/Costs) + (Rate + 0.5*Risk^2)*Years]/ Risk*$\sqrt{\text{Years}}$,
- $d_2 = d_1 - \text{Risk}*\sqrt{\text{Years}}$

6 Data Analysis

6.1 Introduction to Data Analysis

Overall, this study analyzed data from ten years of U.S. GAO reports between 2003 and 2012, providing status information on 526 project entries. The specific detailed focus presented in this study was on the year 2012 for which 47 reports were analyzed. Illustrative examples of the 2012 data analysis are provided throughout this chapter.

6.1.1 Descriptive Data

Of these 47 programs reviewed by the U.S. GAO in 2012, 26 (or 55.32%) were assessed as having sufficiently mature technologies. The programs were at various stages of the Defense Acquisition System lifecycle, 4 being in the Technology Demonstration phase, 18 in the Engineering & Manufacturing Development phase, and 25 being in the Production phase. The means of the ROI of TRA factors were generally indicative of a higher return on investment for TRA knowledge-based activities when the risk of incorporating immature technology was low. The mean value for B/CR was 2.8:1; mean value for ROI% was 175.6%; mean value for NPV was $114,962.5 million; mean value for BEP was 3.6 years; mean value for ROA was $163,967.1 million. (See Table 6-1). The acquisition performance for 2012 reflected a mean value for cost efficiency of 63%, a mean value for schedule efficiency of 81%, and a mean value for performance efficiency of 75%.

Table 6-1. ROI of TRA Factors Summary for 2012 MDAPs

Year	Risk Percent	TRA Cost	Benefit	B/CR	ROI%	NPV	BEP (Years)	ROA
2012	8.0%	$82,935.8	$228,547.6	2.8:1	175.6%	$114,962.5	3.6	$163,957.1

Note. All costs are in millions of dollars.

Source: Analysis of U.S. GAO Selected Acquisition Reports for 2012

In an analysis of the data for each of the military services, the Navy programs represented the largest number of MDAPs within this study for 2012 at 17, followed by the Air Force at 13, the

Army at 11, the Marines at 1, and the MDA at 5. The military service with the largest percentage of its programs proceeding with sufficiently mature technology was the Air Force at 69.23% (or 9/13), followed by the MDA at 60% (or 3/5), the Navy at 52.94% (or 9/17), the Army at 45.45% (or 5/11), and the Marines at 0% (or 0/1). (See Table 6-2).

Table 6-2. Maturity of Critical Technologies Summary for 2012 MDAPs

Year	Number Selected	Total Mature	Total %Mature	Army	Mature	%Army	Navy	Mature	%Navy
	47	26	55.32%	11	5	45.45%	17	9	52.94%
2012	Air Force	Mature	%Air Force	Marines	Mature	%Marines	MDA	Mature	%MDA
	13	9	69.23%	1	0	0.00%	5	3	60.00%

Source: Analysis of U.S. GAO Selected Acquisition Reports for 2012

6.1.2 ROI of TRA Factors Data

Cost of TRA, and Benefit of TRA are two critical factors that drive the majority of the remaining set of factors. Cost of TRA data was modeled at 10% of the total program cost. This comprises an estimated cost of 1.5% for the actual assessment activities, and 8.5% for the TRA enabling engineering activities, including technology demonstrations leading into milestone B (Azizian, Mazzuchi, Sarkani, & Rico, 2011b; DoD, 2011a). Benefit of TRA was based upon several U.S. GAO reports generated over the last decade that have indicated a cost benefit of at least 29.7% of total program cost for those programs that sufficiently matured their critical technologies before starting development (GAO, 2006; GAO, 2007a; GAO, 2008a; GAO, 2011). Factor B/CR reflected a trend similar to ROI%, specifically when technological risk was low, ROI%, and B/CR reflected higher return valuations, however BEP correspondingly reflected shorter time period to reach the breakeven point. When risk was high, ROI%, and B/CR reflected lower return valuations, whereas BEP would reflect a longer time period to reach the breakeven point. Factors NPV and ROA reflected trends similar to risk, specifically when risk was low, NPV and ROA reflected lower return valuations. When risk was high, NPV and ROA reflected higher return valuations. It's noteworthy that in a comparison analysis of the NPV and ROA valuations, ROA consistently provided higher valuations than NPV as risk increased. When risk decreased, the difference between NPV and ROA valuations also decreased. This is a reflection of the added risk component utilized in the ROA model, in addition to the rate. These results are consistent with that experienced by other researchers, specifically that real options analysis provides higher value assessments than NPV, or other discounted cash flows methods, when an investment includes an element of high risk exposure (Kodukula & Papudesu, 2006; Trigeorgis, 2005; Neely III & de Neufville, 2001; Luehrman, 1995).

6.1.3 Acquisition Performance Data

For acquisition performance, the data reflects a mix of management decisions based upon the overall program environment. While it is clear from the 2012 data that overall acquisition performance did not achieve parity or better, the flexibility of the manager to react to his/her programmatic environment provides a powerful and valuable tool to help mitigate program risk caused by immature technology. Specifically, the program manager has the option to reduce the total quantity of systems ordered when schedule or cost exceed planned estimates. This would leave the funds budgeted unchanged, but the planned acquisition quantities would reflect a negative realization of the original plan. Similarly, the program manager, when confronted with technical performance issues, may choose to extend the program schedule and/or increase its allocated budget in order to acquire the desired quantity of systems. These results are similar to that found by Wood (2013), where he analyzed program success in relation to cost, schedule, and performance measurements. He posited that when issues arose, trade-offs between these three attributes were made, however that the program manager could generally only preserve two of the three. A more detailed case study is recommended to investigate the relationship of incorporating immature critical technology and the circumstances that contribute to the trade-offs between cost, schedule, and performance efficiency.

6.2 Cost Analysis of TRAs

The 2012 study by the U.S. GAO provided detailed cost data of 47 U.S. DoD programs, which is the first required input for determining the ROI of TRAs (GAO, 2012). The R&D cost data however seemed to reflect inconsistencies which were not present in the total cost data. A possible explanation may be in how the U.S. DoD allocates funding between R&D and E&MD activities, sometimes to facilitate program survival or mission expediency. Although the R&D phase is the most appropriate timeframe to mature and stabilize the critical technology for a program, and most appropriate for use in technology maturity studies, the basis for cost estimation used in this study was total program costs (see Table 6-3).

Table 6-3. Illustrative Cost Data from 47 Major U.S. DoD Weapon System Programs

No.	Service	Type	Acronym	Program Name	R&D Cost	Total Cost
5	Air Force	SATCOM	B-2 Spirit	B-2 Extremely High Frequency (EHF) SATCOM Capability Increment 1	$497.7	$625.2
30	Navy	Navigation	JPALS	Joint Precision Approach and Landing System	$753.5	$983.3
42	Air Force	Munition	SDB II	Small Diameter Bomb Increment II	$1,642.5	$4,695.6
4	Army	C^2	IAMD	Army Integrated Air and Missile Defense	$2,019.8	$5,528.8
47	Army	C^2	WIN-T Inc 3	Warfighter Information Network-Tactical (WIN-T) Increment 3	$2,222.3	$13,871.4
15	Navy	Ship	DDG 1000	DDG 1000 Destroyer	$10,378.4	$20,985.6
18	Joint	Airplane	JSF	F-35 Lightning II (Joint Strike Fighter)	$58,387.6	$326,535.2

Note. All costs are in millions of dollars.

Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

6.3 Risk Analysis of TRAs

The successful development of complex systems has always rested heavily upon the ability to proactively manage and mitigate the risks of the total acquisition. Management of risk is a key element in the operational planning of any major system development. Identifying and quantifying the technological risk of a program may have been challenging in the past, however the U.S. GAO study of 47 U.S. DoD programs provided the necessary information for estimating risks: (a) total cost, and (b) technology maturity (GAO, 2012). Technology maturity may be defined as the proportional relationship between immature and total critical technologies. Cost risk can be equated to a ranking of total costs within a portfolio. Technology risk can be equated to a ranking of technology maturity within a portfolio. Combined risk may be equated to a composition of both cost and moderated technology risks. Finally Risk% can be equated to a ranking of combined risk within a portfolio (see Table 6-4).

6.4 Benefit Analysis of TRAs

Although obtaining cost data has traditionally been scarcely available, it appears to be becoming more common. No matter the specific subject, the biggest challenge in performing ROI studies has been identifying benefit data (Phillips, 1997). However, the U.S. GAO's study of 47 U.S. DoD programs provided the necessary information for estimating the economic benefits of performing TRAs thereby helping to illuminate the benefits of technology stability and maturity (GAO, 2012). Three key data points for calculating the benefits of TRAs were made available within this U.S. GAO study: (a) technology maturity, (b) total costs, and (c) technology stability and maturity average cost savings (see Table 6-4). Utilizing total costs, and an overall Risk% as determined in the prior section, the benefits of TRA may then be estimated. Benefits are a product of total costs, risk, and an average reported benefit of 29.7% (GAO, 2007a). Other studies of the benefits of acquisition reforms have been performed in the past as well (Lorell & Graser, 2001). After a sensitivity analysis of the initial results, benefits were moderated and smoothed by the normalized costs. In other words, programs with higher costs received a lower allocation of benefits in the final analysis.

Table 6-4. Illustrative Benefit Data from 47 Major U.S. DoD Weapon System Programs

No.	Program	Total Cost	Maturity	Cost Risk	Tech. Risk	Com. Risk	Risk%	Benefit
5	B-2 Spirit	$625.2	100.0%	0.00	0.00	0.00	0.2%	$185.4
30	JPALS	$983.3	0.0%	0.00	1.00	0.10	9.8%	$266.3
42	SDB II	$4,695.6	0.0%	0.01	1.00	0.11	10.9%	$1,257.9
4	IAMD	$5,528.8	0.0%	0.02	1.00	0.12	11.1%	$1,477.5
47	WIN-T Inc 3	$1,387.1	15.0%	0.04	0.85	0.13	12.1%	$3,669.6
15	DDG 1000	$20,985.6	25.0%	0.06	0.75	0.14	13.3%	$5,488.7
18	JSF	$326,525.2	50.0%	1.00	0.50	1.05	100%	$9,698.1

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

6.5 Value Analysis of TRAs

A multitude of economic equations, such as cost, benefit, B/CR, ROI%, NPV, BEP, and ROA, have been introduced in the business community since of the dawn of the Industrial Revolution to help estimate the value of an investment (Rico, 2007). B/CR can be equated to a proportional relationship of benefits to costs. ROI%, which has been a longstanding tool in the business community, is a proportional relationship of benefits minus costs, divided by costs (Phillips, 1997). NPV incorporates the value of money over time (i.e. the impact of inflation upon an investment) and therefore is considered a better estimate of business value than ROI%. BEP may be equated to a proportional relationship of costs to NPV multiplied by the investment timeframe. ROA was initially introduced in the 1970's as an assessment tool to value the benefit of delaying or altering an investment(s) due to risk presence (Black & Scholes, 1973). Rico (2007) posits that ROI% may be used for assessing short-range benefits, NPV for mid-range benefits, and ROA for longer range benefits. All five of these ROI of TRA factors: B/CR, ROI%, NPV, BEP, ROA, have been incorporated into this study of the economic and risk impact of performing TRAs on MDAPs (see Table 6-5).

Table 6-5. Illustrative ROI Data from 47 Major U.S. DoD Weapon System Programs

No.	Program	TRA Cost	Benefit	B/CR	ROI%	NPV	BEP	ROA
5	B-2 Spirit	$62.5	$185.4	3.0:1	196.5%	$98.0	3.2 Years	$136.7
30	JPALS	$98.3	$266.3	2.7:1	170.8%	$132.2	3.7 Years	$189.7
42	SDB II	$469.6	$1,257.9	2.7:1	167.9%	$619.6	3.8 Years	$892.2
4	IAMD	$552.9	$1,477.5	2.7:1	167.2%	$726.5	3.8 Years	$1,046.9
47	WIN-T Inc 3	$1,387.1	$3,669.6	2.6:1	164.5%	$1,790.4	3.9 Years	$2,589.3
15	DDG 1000	$2,098.6	$5,488.7	2.6:1	161.5%	$2,654.1	4.0 Years	$3,854.4
18	JSF	$32,652.5	$9,698.1	0.3:1	-70.3%	-$24,256.0	-6.7 Years	$5,768.8

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

6.5.1 Analysis of B-2 Spirit.

Let's examine the results for the B-2 Spirit program. The Air Force's B-2 Spirit stealth bomber is designed to be a long-range, strategic heavy bomber with a low-observable signature capable of penetrating advanced and compact air defenses. The B-2 Spirit EHF SATCOM Increment 1 program analyzed in this study "upgrades the aircraft's flight- management computer processors, increases data-storage capacity, and establishes a high-speed network that will serve as the foundation for future B-2 upgrades" (GAO, 2012, p. 49). The program acquisition state was near the end of its E&MD phase for this study. Upon determination of costs and benefit of TRAs for the B-2 Spirit, our model estimates values for the other five metrics (i.e., B/CR, ROI%, NPV, BEP, and ROA). The B/CR valuation reflects a significant positive value added between the cost of implementing TRA and knowledge-based practices, and the potentially derived benefits. Essentially three dollars of benefit for every dollar expended is gained or saved (i.e. efficiency). The ROI% valuation, also reflects a simple cost-benefit ratio, less the costs, without consideration for the time value of money, and indicates an almost 200% return on the program's investment in TRA practices, or two dollars saved for every dollar invested. The NPV valuation, incorporates the time value of money to the economic evaluation, and provides the present value of the estimated return. In a traditional business decision making scenario, a positive difference between NPV and cost, provides justification to proceed with the program or investment, and in this case the result is approximately $98 million. The BEP valuation reflects being able to recoup (in efficiency gains) the full initial cost of investment in TRA practices in just over three years. Finally, the ROA valuation results in an estimated return of $136.7 million, which is $38.7 million more value than the NPV estimate, and an estimated return of $74.2 million above the cost of implementing TRA practices. Note, the option to delay or abandon this effort would not be purchased or considered in this case since the overall program and technological risks are sufficiently low. In this example of the B-2 Spirit program, all of the key ROI metrics are reflective of a sufficiently mature technology base. Furthermore, it indicates the technological risk of proceeding into the next development phase is low in comparison to other MDAPs within the U.S. DoD portfolio.

6.5.2 Analysis of WIN-T Inc 3.

"WIN-T is the Army's high-speed, high-capacity backbone communications network <which> connects Army units with higher levels of command, and provides the Army's tactical portion of the Global Information Grid…<The WIN-T Inc 3 program provides> a full networking on-the-move capability" (GAO, 2012, p. 135). The program acquisition state was near the end of its E&MD phase for this study. Our analysis of the program's B/CR metric reflects a favorable valuation. It indicates for every dollar expended, more than twice the amount is realized as benefit. The ROI% valuation also reflects an almost 165% return on the program's investment in TRA practices, or $1.65 saved for every dollar invested. The NPV valuation reflects a significant savings of approximately $1,790.4 million. The BEP valuation indicates the ability to recoup the initial cost of investment in TRA practices in just under four years. Finally, the ROA valuation results in an estimated return of $2,589.3 million, which is $798.9 million more value than the NPV estimate, and an estimated return of $1,202.2 million above the cost of implementing TRA practices. Note, the option to delay or abandon this effort would not be purchased or considered in this case since the overall program and technological risks are sufficiently low. In this example of the WIN-T Inc

3 program, several of the key ROI metrics are reflective of a sufficiently mature technology base. Furthermore, it indicates the technological risk of proceeding into the next development phase is low in comparison to other MDAPs within the U.S. DoD portfolio.

6.5.3 Analysis of JSF (F-35) Program.

The Joint Strike Fighter (JSF) program, also known as the F-35, is a fifth generation family of single-seat, single-engine, multi-role fighter aircraft being developed for the Air Force, Marines, Navy, and U.S. allies to perform air defense, reconnaissance, and ground attack missions with stealth capability (GAO, 2012). The program acquisition state was in the early portion of its P&D phase for this study. Our analysis of the B/CR metric reflects a less than favorable valuation. It indicates for every dollar expended, less than a third of every dollar is realized as benefit. This is reflective of about half of the Joint Strike Fighter's (JSF's) critical technologies not being sufficiently mature before E&MD. The ROI valuation reflects a negative return of -70.3%, and the NPV valuation reflects a significant negative valuation of -$24.3 million. In a traditional business decision making scenario, a negative difference between NPV and cost may provide sufficient justification to not proceed with the program or investment, and in this case the result is -$24,256 million. The BEP valuation reflects not being able to recoup the full initial cost of investment in TRA practices due to the remaining immaturity of critical technologies and unstable requirements. Finally, the ROA valuation results in an estimated return of $5,768.8 million, which is $30,024.8 million more value than the NPV estimate, and is an estimated $26,883.7 million less than the cost of implementing TRA practices. Note, the option to delay or abandon this effort would be purchased or considered in this case since the overall program and technological risks are sufficiently high within the portfolio. In this example of the JSF program, all of the key ROI metrics are reflective of an insufficiently mature technology base, and that the technological risk of proceeding into the next development phase is high in comparison to other MDAPs within the U.S. DoD portfolio.

6.5.4 Portfolio Analysis.

The portfolio excerpt represented in Table 6-5 provides a forum for illustrating the use of the research framework described herein to manage the risk within a program portfolio. Specifically, in comparing the 7 programs, six reflect strong B/CRs and would merit continued economic support for development. One, the F-35, reflects a comparatively low B/CR, and should cause the decision maker to consider delaying further investment until a higher level of technical maturity and lower program risk is achieved, or abandoning the entire effort. In particular, note that besides the ROA factor, the other factors B/CR, ROI%, NPV, and BEP reflect a negative valuation. The ROA measure for the F-35 delaying 5 years provides an estimated ROI of $5,768.8 million. Herein lies one of the key benefits of incorporating the ROA metric into the portfolio analysis tool suite of the decision maker. The ROA measure clearly shows the potential positive ROI opportunity that may be realized by delaying further development, and allowing additional time to mature the program's CTs. This finding is in alignment with other studies regarding the value and insight of ROA (Trigeorgis, 1993; Dixit & Pindyck, 1995; Luehrman, 1995; Fichman, Keil, & Tiwana, 2005). Additional analysis of the F-35's ROA valuation, however, reveals that when it is applied into the BEP valuation, it results in an estimation of 28.3 years to achieve breakeven. This insight might provide the decision maker more reason to consider abandoning the program.

6.6 Summary of TRAs

Figure 6-1 provides an illustrative histogram of the programs that have been highlighted so far in this study. It provides a comparison of three of the ROI of TRA factors: B/CR, Risk, and ROA. It highlights the relationship between Risk and ROA, reflecting that when program risk trends high, the corresponding ROA valuation trends high as well. This may be used as an indication to the decision maker to consider delaying the development phase of a program until sufficient technological maturity has been achieved by the critical technologies being incorporated into a program. The chart also highlights the relationship between Risk and B/CR, where when program risk is low, the opportunity for high B/CR is greatest. Moreover, when risk is low, it's an indication of a mature technological base upon which the program can develop. These findings are in alignment with research by others such as Kodukula & Papudesu (2006), Reagan & Rico (2012).

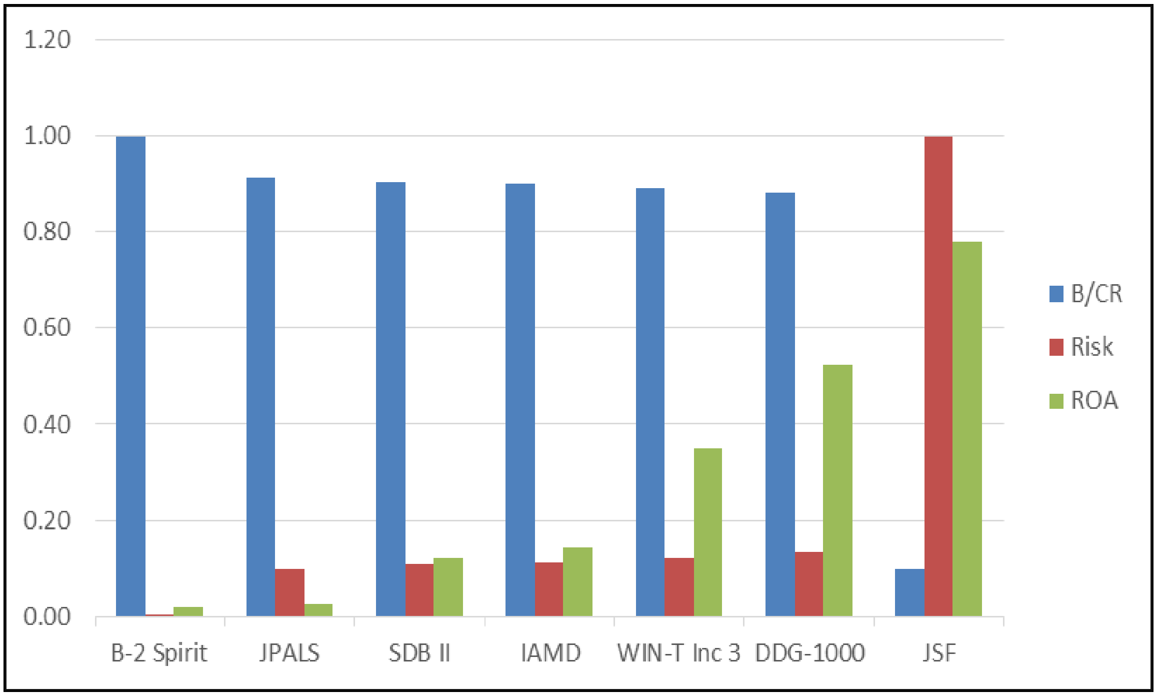


Figure 6-1. Illustrative B/CR, Risk, and ROA Data from 47 U.S. DoD Weapon Systems

6.7 Comparative Analysis of Military Branches

As discussed previously in section 6.5, there are a multitude of economic equations, many of which were first introduced during the Industrial Revolution, to help ascertain the business value of an investment such as cost, benefit, benefit/cost ratio (B/CR), return on investment percentage (ROI%), net present value (NPV), breakeven point (BEP), and real options analysis (ROA) (Rico, 2007). In this section, all five vantage points are utilized in analyzing the acquisition data for each of the military branches, specifically, the Army, Navy, and Air Force: (a) B/CR, (b) ROI%, (c) NPV, (d) BEP, and (e) ROA (see Table 6-6, 6-7, 6-8).

Table 6-6. Illustrative Army ROI Data from 2012 MDAP Portfolio

No.	Program	TRA Cost	Benefit	B/CR	ROI%	NPV	BEP	ROA
17	Excalibur	$178.1	$472.5	2.7:1	165.4%	$231.1	3.9 Years	$333.8
28	JHSV	$367.4	$851.5	2.3:1	131.7%	$369.9	5.0 Years	$567.6
23	Gray Eagle	$515.9	$983.3	1.9:1	90.6%	$335.5	7.7 Years	$624.8
4	IAMD	$552.9	$963.0	1.7:1	74.2%	$280.9	9.8 Years	$608.2
31	JTRS AMF	$816.1	$1,039.9	1.3:1	27.4%	$84.4	48.4 Years	$660.8
32	JTRS HMS	$835.8	$1,035.8	1.2:1	23.9%	$61.1	68.4 Years	$658.8
3	AH-64D Block IIIa	$1,073.7	$1,141.4	1.1:1	6.3%	-$85.3	-62.9 Years	$729.7

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

Table 6-7. Illustrative Navy ROI Data from 2012 MDAP Portfolio

No.	Program	TRA Cost	Benefit	B/CR	ROI%	NPV	BEP	ROA
25	IDECM	$82.2	$239.0	2.9:1	190.9%	$124.8	3.3 Years	$175.0
38	NMT	$188.1	$532.2	2.8:1	183.0%	$272.7	3.4 Years	$385.7
45	VTUAV	$261.5	$725.7	2.8:1	177.5%	$366.9	3.6 Years	$522.0
41	SSC	$441.3	$1,165.3	2.6:1	164.1%	$567.8	3.9 Years	$821.7
37	MUOS	$697.8	$1,709.2	2.4:1	144.9%	$782.2	4.5 Years	$1,166.3
11	BAMS	$1,305.2	$2,605.4	2.0:1	99.6%	$950.8	6.9 Years	$1,666.0
16	E-2D AHE	$1,774.7	$2,920.8	1.6:1	64.6%	$754.4	11.8 Years	$1,843.1

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

Table 6-8. Illustrative Air Force ROI Data from 2012 MDAP Portfolio

No.	Program	TRA Cost	Benefit	B/CR	ROI%	NPV	BEP	ROA
27	JASSM-ER	$373.0	$1,097.0	2.9:1	194.1%	$576.9	3.2 Years	$806.5
21	GPS III	$421.1	$1,236.7	2.9:1	193.7%	$649.8	3.2 Years	$908.8
19	FAB-T	$468.8	$1,375.3	2.9:1	193.3%	$722.0	3.2 Years	$1,010.2
12	C-130 AMP	$620.4	$1,812.7	2.9:1	192.2%	$949.2	3.3 Years	$1,329.5
40	MQ-9	$1,191.9	$3,429.1	2.9:1	187.7%	$1,777.4	3.4 Years	$2,500.9
43	SBIRS High	$1,826.7	$5,165.1	2.8:1	182.8%	$2,645.7	3.5 Years	$3,742.5
33	KC-46	$4,412.7	$10,464.4	2.4:1	137.1%	$4,648.3	4.7 Years	$7,041.1

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

We examined the model results for each of the military service portfolios. The U.S. Army 2012 portfolio of MDAPs exhibited a wide range of performance. For example, the B/CR performance estimate ranged from 1.1:1 to 2.7:1, and the BEP from -62.9 years to 3.9 years. Conversely, the Navy's B/CR ranged from 1.6:1 to 2.9:1, and the BEP from 11.8 years to 3.3 years, while the Air Force's B/CR ranged from 2.4:1 to 2.9:1, and the BEP from 4.7 years to 3.2 years. This performance may be indicative of a lack of consistent institutional adherence to DoDI 5000.02 by the Army, although further detailed analysis is required. The Navy's 2012 portfolio of MDAPs acquisition performance appears to exhibit more consistency within its portfolio of programs in reaping the benefits of TRA knowledge-based practices than the Army. In particular, a higher percentage of its programs had an B/CR greater than 2:1 and an ROI% of greater than 100%, which may indicate a more effective CT selection process that leverages sufficiently matured technology for incorporation into development programs, although less than that accomplished by the Air Force. The Air Force's 2012 portfolio of MDAPs acquisition performance appears to exhibit even more consistency within its portfolio of programs in reaping the benefits of TRA knowledge-based practices than the Army or Navy. Of particular note is that a higher percentage of the Air Force programs had a B/CR measurement of 2.8:1 or higher, as well as reached the breakeven point sooner (< 3.5 years). This performance may be indicative of a greater efficiency in program acquisition and operation due to greater adherence to knowledge-based practices.

A sampling of the case study analysis performed for each military service portfolio is provided in the following paragraphs. Each case provides additional insight into the potential economic risk associated with development with or without sufficiently mature critical technology.

6.7.1 Analysis of AH-64D Block IIIa.

The Army's Apache Block 3a program (AB3A) is an upgrade of the "AH-64D Longbow helicopters to improve performance, situational awareness, lethality, survivability, and interoperability, and to prevent friendly fire incidents" (GAO, 2012, p. 45). The program acquisition state for this study was in the early stages of the Production and Deployment (P&D) phase. Upon determination of costs and benefit of TRAs for the AH-64D Block IIIa, our model estimates values for the other five metrics (i.e. B/CR, ROI%, NPV, BEP, and ROA). Our analysis of the B/CR metric reflects a less than favorable valuation. It indicates for every dollar expended only a small relative percent (i.e. 10%) is returned as benefit. The ROI% valuation also reflects a simple cost-benefit ratio, less the costs, without consideration for the time value of money, reflects only a 6.3% return on the program's investment in TRA practices, or $.063 saved for every dollar invested. The NPV valuation incorporates the time value of money to the economic evaluation, and provides the present value of the estimated return. In a traditional business decision making scenario, a positive difference between NPV and cost, provides justification to proceed with the program or investment. The NPV valuation here reflects a significant negative valuation of -$85.3 million, and may provide sufficient justification to not proceed with the program or investment. The BEP valuation reflects not being able to recoup the full initial cost of investment in TRA practices due to the remaining immaturity of critical technologies and unstable requirements. Finally, the ROA valuation results in an estimated return of $729.7 million, which is $674.4 million more than the NPV estimate, and is an estimated $344.07 million less than the cost of implementing TRA practices. Note, the option to delay or abandon this effort would be purchased or considered in this case since the overall program and technological risks are sufficiently high within the portfolio. In this example of the Apache Block 3A program, several of the key ROI metrics are reflective of an unstable technology base and cost risk, and that the program risk in proceeding into the next phase is high in comparison to other MDAPs within the U.S. DoD portfolio.

6.7.2 Analysis of MUOS.

The Navy's Mobile User Objective System (MUOS) is "a satellite communication system <that> is expected to provide a worldwide, multiservice population of mobile and fixed-site terminal users with increased narrowband communications capacity and improved availability for small terminal users" (GAO, 2012, p. 111). The program acquisition state for this study was in the early stages of the Production and Deployment (P&D) phase. The B/CR valuation reflects an impressive value added between the cost of implementing TRA and knowledge-based practices, and the potentially derived benefits. Nearly two and half dollars (i.e. ~$2.40) of benefit for every dollar expended is gained or saved (i.e. efficiency). The ROI% valuation indicates an approximate return of 144.9% on the program's investment in TRA practices, or approximately $1.44 saved for every dollar invested. The NPV valuation result is approximately $782.2 million. The BEP valuation reflects being able to recoup (in efficiency gains) the full initial cost of the investment in TRA practices in approximately four and a half years. Finally, the ROA valuation results in an estimated return of $1166.3 million, which is $384.1 million more value than the NPV estimate, and an estimated return of $468.5 million above the cost of implementing TRA practices. Note, the option to delay or abandon this effort would not be purchased or considered in this case since the overall program and technological risks are sufficiently low. In this example of the MUOS program, all of the key ROI metrics are reflective of a sufficiently mature technology base. Furthermore, it indicates the technological risk of proceeding into the next development phase is low in comparison to other MDAPs within the U.S. DoD portfolio.

6.7.3 Analysis of JASSM-ER.

The Air Force's Joint Air-to-Surface Standoff Missile – Extended Range (JASSM-ER) program will "field a next-generation cruise missile capable of destroying the enemy's war-sustaining capability from outside its air defenses. <The> JASSM-ER missiles are low- observable, subsonic, and have a range greater than 500 miles" (GAO, 2012, p. 91). The program acquisition state for this study was in the early stages of the Production and Deployment (P&D) phase. The B/CR valuation reflects an impressive value added between the cost of implementing TRA and knowledge-based practices, and the potentially derived benefits. Nearly three dollars (i.e. ~$2.90) of benefit for every dollar expended is gained or saved (i.e. efficiency). The ROI% valuation indicates an approximate return of 194.1% on the program's investment in TRA practices, or approximately $1.94 saved for every dollar invested. The NPV valuation result is approximately $576.9 million. The BEP valuation reflects being able to recoup (in efficiency gains) the full initial cost of the investment in TRA practices in slightly more than three years. Finally, the ROA valuation results in an estimated return of $806.5 million, which is $229.6 million more value than the NPV estimate, and an estimated return of $432.9 million above the cost of implementing TRA practices. Note, the option to delay or abandon this effort would not be purchased or considered in this case since the overall program and technological risks are sufficiently low. In this example of the JASSM-ER program, all of the key ROI metrics are reflective of a sufficiently mature technology base. It also indicates the technological risk of proceeding into the next development phase is low in comparison to other MDAPs within the U.S. DoD portfolio.

6.7.4 Military Services Portfolio Analysis.

Reviewing the estimated ROI for each portfolio of the military services, it becomes apparent that the majority of the Army's program portfolio listed in Table 6-6 will not provide a return that is sufficient to breakeven within the 5 year marker (i.e. BEP < 5 years) used in this study, even when the B/CR may be estimated greater than 1:1, and the NPV is still positive. Specifically 5 out of the 7 programs fall into this category. A closer look reveals that 2 of the 5 programs, Gray Eagle and IAMD, may present a reasonable opportunity to improve their ROI by investing (purchasing a real option) to further mature their CTs while delaying full scale development and/or production, with ROAs that indicate achieving their projected BEP within 5 years. However for the remaining 3 of 5 programs, JTRS AMF, JTRS HMS, and AH-64D Block IIIa, their ROA measure indicates that even with the option to delay program development, the improvement in ROI will be slow in coming, with BEP valuations of 6.1 years, 6.3 years, and 7.3 years, and consequently may warrant consideration for abandonment of the programs.

The majority of the Navy's MDAPs listed in Table 6-7 will provide a good return, except for 2 out of the 7 programs, specifically BAMS and E-2D AHE. Both of these programs present the opportunity to improve their ROI by investing (purchasing a real option) to further mature their CTs and mitigate program risks while delaying full scale development and/or production. Specifically, their ROA valuations when applied to their BEP valuations resulted in breakeven points of 3.9 years and 4.8 years, respectively.

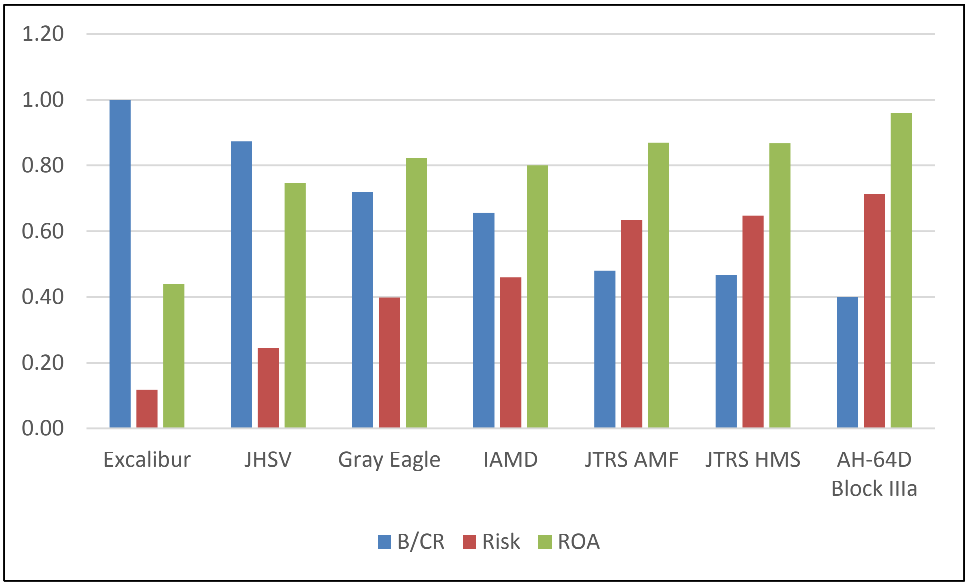
Finally, in analyzing the Air Forces' MDAPs listed in Table 6-8, all of its portfolio programs illustrated in this example are projected to provide a good return, and achieve a BEP within 5 years based upon projected ROI valuations from all measures. Therefore, the decision maker would not have a need to consider purchasing an option (i.e. utilize the ROA method) to delay further development.

6.8 Summary of Data Analysis

Using our model, the data from the U.S. GAO study of the 2012 MDAP portfolio was first sorted by Risk% in ascending order (e.g., programs were sorted by least to greatest risk and size). The data was then filtered by military service. Figures 6-2, 6-3, and 6-4 provide illustrative histograms of each of the services' programs that have been highlighted in this study. The first major finding revealed by this analysis, and consistent across the portfolios of the military services, was that B/CR decreases as program risk and cost increase, which coincides with results from other studies that larger programs are inherently more complex and risk prone versus smaller, shorter duration programs which have exhibited as much as a 90% success rate (Benediktsson & Dalcher, 2005). Also increasing Risk% is indicative of decreasing technology maturity, consequently programs with a larger number of unstable and immature technologies will have a larger risk and lower ROI. The most significant finding is that ROA increases as risk increases and B/CR decreases, especially if risk-reducing acquisition practices are used like evolutionary acquisition, dividing acquisitions in smaller increments, and spiral development (Reagan & Rico, 2012;

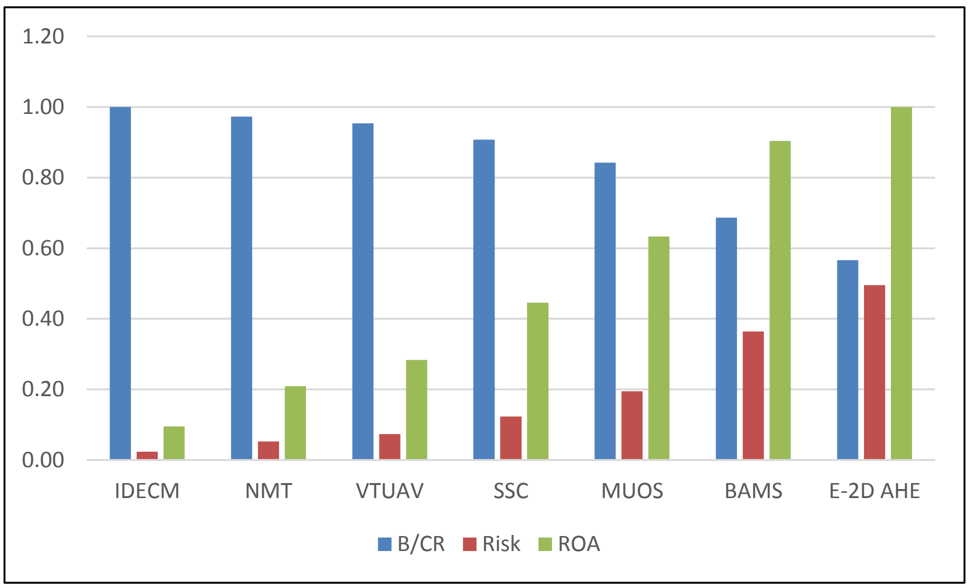
Benediktsson & Dalcher, 2005). Delaying a program due to size and technology instability and immaturity by dividing the scope into numerous smaller increments, spirals, and iterations across the entire acquisition life cycle may result in greater economic benefits for each of the military services.

Lean and agile development approaches are another means of delaying a program until its technologies are sufficiently stable and mature, essentially by investing earlier and in smaller amounts in iterations and releases (Duvall, 2012). This supports the concept provided by other studies which reflect that when there is heightened risk, the flexibility to delay a decision or investment can be quite valuable (Trigeorgis, 1993; Dixit & Pindyck, 1995; Luehrman, 1995; Fichman, Keil, & Tiwana, 2005). It can be seen from the earlier examples that the use of classical economic valuation methods may provide useful management insight into the state of an acquisition program. In addition, ROA may provide the U.S. DoD overall, and each military service specifically, a useful estimate of the value of deferring a program until its technologies are sufficiently mature, even when NPV indicates no further investment may be warranted; hence our motivation for including ROA in our process framework (Kodukula & Papudesu, 2006).



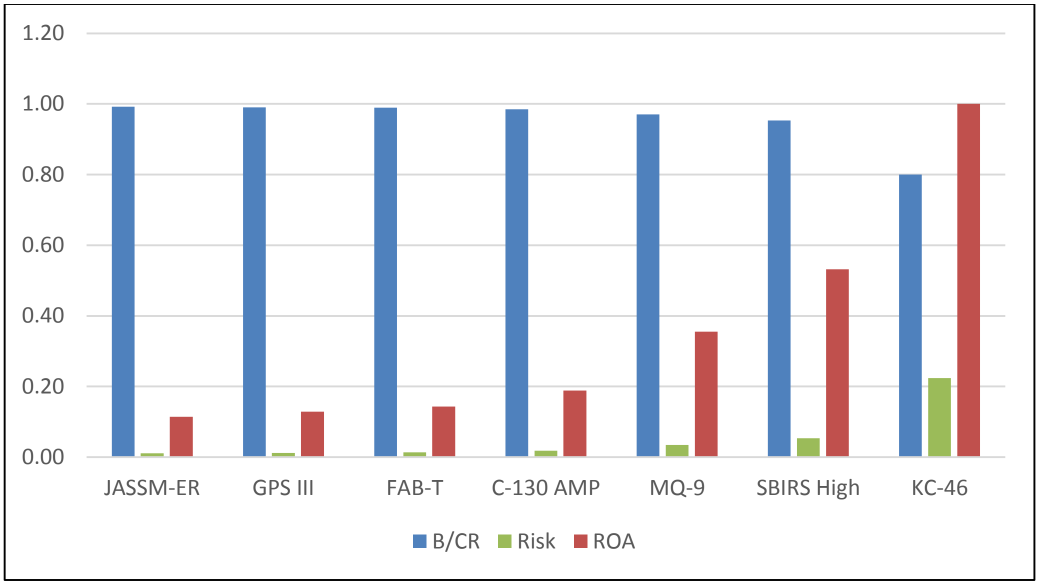
Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

Figure 6-2. Illustrative Army B/CR, Risk, and ROA Data from 2012 MDAP Portfolio



Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

Figure 6-3. Illustrative Navy B/CR, Risk, and ROA Data from 2012 MDAP Portfolio



Source: Analysis of U.S. GAO Selected Acquisition Reports 2012.

Figure 6-4. Illustrative Air Force B/CR, Risk, and ROA Data from 2012 MDAP Portfolio

6.9 Trend Analysis over a Decade (2003-2012)

We expanded our study to examine all the U.S. GAO assessment reports generated between 2003 and 2012 (GAO, 2003, 2004, 2005a, 2006, 2007a, 2008a, 2009a, 2010, 2011, & 2012). For each of the military services, and the U.S. DoD overall (including the Marines and Missile Defense Agency), a few trends seem to become apparent as reflected in Table 6-9: (a) an overall lowering of Risk % in the weapon systems portfolio, which is indicative of an overall reduction in the incorporation of immature technology into development programs (b) an overall improvement in B/CR, indicating growth in execution efficiency (c) overall growth in ROI% indicating a trend of maximizing return on technology choices, (d) improvement in BEP indicating less time needed before benefits of technology readiness exceeds costs, and (e) an overall lowering of ROA valuation as Risk% is lowered indicating more programs are waiting for critical technologies to mature before entering into development. The trends seem to indicate that the incorporation of TRAs and knowledge-based practices into the acquisitions of each military service may indeed improve cost, schedule, and technical performance of those programs, and consequently the overall U.S. DoD weapon systems portfolio.

Table 6-9. Summary ROI of TRA Analysis of U.S. GAO MDAP Data from 2003-2012

Year	No. Pgms	Critical Technologies			Risk%	TRA Cost	Benefit	B/CR	ROI	NPV	BEP (Yrs)	ROA
		Immature	Tot	Mature								
2012	47	103	345	70.1%	8.0%	$82,935.8	$228,547.6	2.8:1	175.6%	$114,962.5	3.6	$163,957.1
2011	49	106	371	71.4%	8.7%	$83,456.8	$228,483.7	2.7:1	173.8%	$114,386.1	3.6	$163,487.4
2010	55	105	372	71.8%	9.6%	$87,909.6	$238,416.2	2.7:1	171.2%	$118,533.9	3.7	$169,952.1
2009	59	177	420	57.9%	10.2%	$97,444.3	$262,715.5	2.7:1	169.6%	$130,039.9	3.7	$186,825.9
2008	72	208	466	55.4%	8.7%	$106,304.8	$291,048.4	2.7:1	173.8%	$145,712.6	3.6	$208,258.1
2007	62	241	451	46.6%	10.0%	$87,997.8	$237,794.1	2.7:1	170.2%	$117,907.0	3.7	$169,261.4
2006	51	225	428	47.4%	11.2%	$84,425.8	$225,533.7	2.7:1	167.1%	$110,862.8	3.8	$159,782.8
2005	54	251	443	43.3%	11.3%	$80,422.3	$214,634.1	2.7:1	166.9%	$105,428.4	3.8	$152,001.2
2004	51	193	391	50.6%	10.9%	$67,429.3	$180,664.2	2.7:1	167.9%	$89,007.0	3.8	$128,150.2
2003	26	39	117	66.7%	12.0%	$47,702.0	$126,332.6	2.6:1	164.8%	$61,688.8	3.9	$89,182.2

Note. All costs and benefits are in millions of dollars.
Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012.

Additionally, the data seems to indicate what appears to be an inconsistency in the level of adherence and commitment by the individual military services in their execution of knowledge-based acquisition practices mandated by Congress and the U.S. DoD (GAO, 2003, 2004, 2005a, 2006, 2007a, 2008a, 2009a, 2010, 2011, & 2012). Specifically, as reflected in Table 6-10, we found the Army averaged 40% of its MDAPs CTs being sufficiently mature, the Navy averaged 57%, and the Air Force averaged 67%. Perhaps even more telling is the commitment level of adherence to TRA knowledge-based practices appears to have carried through to the level of acquisition performance success realized during this decade. This appears to be consistent with results from other studies by the U.S. GAO and U.S. DoD that technology maturity, or lack thereof, is a predictor of acquisition performance (GAO, 2008b; DoD, 2008). Moreover, weapon systems that use mature technologies will have better acquisition performance than those using immature technologies (Robinson, 2009; Mandelbaum, 2009).

Table 6-10. 2003-2012 U.S. DoD Military Services CT Maturity Assessments

Year	Army Critical Technologies			Navy Critical Technologies			Air Force Critical Technologies		
	Im-mature	Total	Mature	Im-mature	Total	Mature	Im-mature	Total	Mature
2012	35	83	57.8%	34	109	68.8%	25	74	66.2%
2011	44	122	63.9%	31	102	69.6%	29	82	64.6%
2010	43	106	59.4%	35	104	66.3%	8	72	88.9%
2009	83	124	33.1%	40	100	60.0%	18	82	78.0%
2008	81	128	36.7%	48	117	59.0%	30	96	68.8%
2007	91	125	27.2%	71	160	55.6%	44	108	59.3%
2006	99	140	29.3%	63	103	38.8%	44	98	55.1%
2005	104	118	11.9%	76	130	41.5%	47	105	55.2%
2004	85	109	22.0%	60	102	41.2%	30	102	70.6%
2003	7	19	63.2%	10	33	69.7%	11	37	70.3%
Avg	**67**	**107**	**40.45%**	**47**	**106**	**57.06%**	**29**	**86**	**67.70%**

Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012.

Acquisition performance was analyzed on a unit basis. It was decomposed into three components: (a) cost efficiency, (b) schedule efficiency, (c) performance efficiency. Cost efficiency was a reflection of the ratio of actuals versus planned unit cost. Schedule efficiency was a reflection of the ratio of actuals versus planned schedule. Performance efficiency was a reflection of the ratio of actuals versus planned units acquired. See Table 6-11. Over the 10 year period from 2003-2012, the mean cost efficiency was 0.79, with a standard deviation of 0.092. The mean schedule efficiency was .80, with a standard deviation of 0.027. The mean performance efficiency was 0.73, with a standard deviation of 0.157. The inefficiencies reflected were analogous to that found in other studies by Bair (1994) and Fox (2011), where political and technological aspects of acquisition performance were assessed.

Table 6-11. Acquisition Performance Summary for 2003-2012 MDAPs

Year	PEFF	SEFF	CEFF
2012	0.75	0.81	0.63
2011	0.75	0.79	0.81
2010	0.70	0.78	0.76
2009	0.46	0.79	0.71
2008	0.93	0.78	0.81
2007	0.79	0.79	0.81
2006	0.85	0.86	0.81
2005	0.88	0.84	0.87
2004	0.72	0.82	0.97
2003	0.47	0.82	0.73

Source: Analysis of U.S. GAO Selected Acquisition Reports 2003-2012

6.10 Data Sensitivity Analysis

We have also investigated what would happen if we were to choose different values from the baseline set used for this study (i.e. where t=5 years and r=5%), for the exercise period as well as the discount interest rate used in the ROA calculation and the corresponding alignment with the NPV ROI of TRA factor. That analysis led to the following results reflected in this section.

As you might expect as the exercise period extends or is farther away (t=10 years), the NPV value trends lower, and as the exercise periods gets closer (t=1 or 3 years) the NPV value trends higher. On the other hand ROA trends higher when the exercise period extends, and trends lower when the exercise period gets closer.

Our analysis also showed that when the rate trends lower (r=1, 2, 3, or 4 %), NPV trends higher, and when the rate trends higher (r=10%), NPV trends lower. On the other hand ROA trends lower when the rate trends lower, and trends higher when the rate trends higher.

The data tends to indicate the opportunity to delay investment decisions until technologies are sufficiently mature improves execution outcomes. This is consistent with the findings of several other studies (Kodukula & Papudesu, 2006) (Mun & Housel, 2006) (Trigeorgis, 2005) (Shishko, Ebbeler, & Fox, 2004) (Gray, Arabshahi, Lamassoure, Okino, & Andringa, 2005).

7 Conclusion

7.1 Final Summary.

The U.S. DoD continues to invest enormous quantities of resources in its portfolio of weapon systems for the expressed purpose of maintaining their nation's military and even peacekeeping readiness. Acquisition performance continues to struggle and manifest itself in the form of cost and schedule overruns and reduced DoQs. This remains so in spite of five decades of deliberate improvements to acquisition, program management, systems engineering, and even software engineering practices, now frequently referred to as early, knowledge-based practices by the U.S. GAO. For several decades the U.S. DoD and Congress have endeavored to institute, revamp, refine, tweak, overhaul, and reform the defense acquisition system in attempts to structure a system of procuring major weapon systems as efficiently, effectively, and affordably as possible unfortunately without achieving significant sustained improvement (Bair, 1994; GAO, 1988; Fox, 2011; DoD, 2013b). Economic evidence is beginning to emerge indicating multi-million and even multi-billion dollar investments in these knowledge-based practices, especially TRAs as a means of achieving technology maturity, are starting to pay off in both defense and commercial industries.

We developed a process framework to evaluate the costs and benefits of the current defense acquisition portfolio using classical techniques such as B/CR, NPV, and ROA. We have shown there is added ROI valuation due to the use of TRAs for MDAPs. We have also shown that the ability to delay a decision to move into development/production until CTs (and associated risk) are sufficiently matured (mitigated) may provide significant cost benefit to a program. We have defined a set of valuation metrics for ROI of TRAs that includes costs, benefits, B/CR, ROI%, NPV, BEP, and ROA. Indeed, used along with traditional discounted cash flow methods, real options analysis provides additional insight for the decision maker into the cost and technology risk for MDAPs, and enhanced opportunities to maximize ROI from new complex technologies targeted for MDAPs by use of the TRA process framework. The ROA measure supports a) valuation of the decision to delay, b) identification and quantification of risk associated with CTs, c) prioritization of program development, and mitigation of risks.

This study has also revealed an inconsistency between the military services in their commitment level of adherence to knowledge-based practices as mandated by DoDI 5000.02. In particular, although the evidence continues to mount indicating that programs with immature technology experience cost, schedule, and performance shortfalls, the military services appear to discount this risk, continuing to allow immature technology into their development programs. Table 6-10 speaks clearly to this issue where over the past decade the Army averaged only 40% of its MDAP CTEs being sufficiently mature, the Navy averaged 57%, and the Air Force averaged 67%.

The framework introduced in this study was made possible by the emergence of public acquisition data and practical top-down parametric models. Using this process framework, an analysis of acquisition costs, technology maturity, risks, TRA costs, and TRA benefits indicates that there may indeed be some economic evidence to support knowledge-based practices. While many within the acquisition community may be willing to continue investing in knowledge-based practices based on face validity, some are beginning to question the exact economic benefits of such activities. This study was designed to help this latter group of people who wish to begin the long journey of collecting economic data on TRAs and reasoning about it using classical economic models. This study was also designed to help decision makers such as U.S. DoD policymakers, acquisition executives, program managers, systems engineers, software engineers, and other key decision-makers and analysts in understanding the economic impacts of knowledge-based practices. Once we, as a community, are able to measure our performance, then we can begin making significant strides towards improving the outcome of our investments in major weapon system acquisitions.

7.2 Limitations.

Although additional U.S. GAO studies, along with this study and other research, are beginning to emerge, which show improved acquisition performance and economic benefits of knowledge-based practices, there is still much work to be done. For instance, better and finer grained data need to be collected on the precise investment costs associated with the TD phase, full-scale system prototypes, and the TRA process itself. Furthermore, while the U.S. GAO studies provide early broad-sweeping estimates of the benefits of knowledge-based practices, micro-economic studies of the impacts, outcomes, and benefits of technology maturity still need to be performed. Additionally, although this research has focused primarily on the U.S. DoD and its ability to acquire major complex weapon systems, it's applicability to non-U.S. defense agencies might be assumed, but should be investigated further. Of course, data quality is the key to any quantitative analysis, so the assumptions behind the acquisition data need closer scrutiny, examination, and justification. This study was designed to begin the conversation associated with those who wish to understand the quantitative economic benefits of TRAs, rather than end it. This study was not intended to be an exhaustive economic evaluation of the costs and benefits of TRAs, but rather it was intended to be an initial exploratory investigation into the economic benefits of TRAs. And, of course, this was not a definitive analysis of the costs and benefits of TRAs. That being said, this study still provides significant progress towards understanding these dynamics.

7.3 Future Recommendations.

There are a number of future activities that need to be performed in order to develop an exhaustive economic analysis of knowledge-based practices, TRAs, and technology maturity. First of all, the defense and commercial industries need to collect exact costs associated with certain practices, especially TD phase costs, the development of full-scale system prototypes, and IRT costs as well. These need to be divided by the type of domain in which the acquisition is performed (i.e., missiles, aircraft, maritime, spacecraft, information technology, etc.). Exact E&MD, P&D, and O&S costs need to be collected as well. As mentioned earlier, micro-economic studies of specific technology impacts need to be known, especially when a cost, schedule, performance, or DoQ can be attributed to specific CTs and an inability to sufficiently mature them. Of course, specific metrics, models, and economic valuation methods should be agreed upon. For instance, are acquisition costs, schedules, technical performance, or DoQs sufficient for cost and benefit analysis, or should B/CR, NPV, and ROA be used as well? Finally, if ROA is considered as a valuable technique, then a standard method of estimating its risk component needs to be devised as well (Conrow, 2009; Wilhite & Lord, 2006). Even more importantly than TRAs and technology maturity alone, the costs and benefits of other knowledge-based practices need to enter into the discussion as well, specifically the costs and benefits of lean and agile methods (Reagan & Rico, 2010). These newer approaches are now being used by a growing proportion of defense and commercial development programs of all shapes, sizes, domains, and purposes to reduce acquisition risks (Duvall, 2012). In addition, we recommend a more in-depth study of the commitment level to knowledge-based practices between the military services to ascertain whether there are inherent institutional barriers that inhibit fuller and more consistent implementation of DoDI 5000.02 and associated commercial best practices.

In closing, it should also be noted that the TRA tool should be considered one of several management tools used by decision makers in the acquisition and execution of their program. The TRA process does not provide a panacea of right choices, but may be used in the context of other empirical input to assist the decision maker in selecting the optimum path to follow.

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Appendix A. U.S GAO Source Data (2003-2012)

The following tables contain data which were extracted from the annual U.S. GAO Selected Acquisition Reports published between 2003 and 2012 (GAO, 2003, 2004, 2005a, 2006, 2007a, 2008a, 2009a, 2010, 2011, & 2012). This data provided the fundamental source of information utilized for analysis in this study. These reports provided a summary of each MDAP in a 2-page format. Where data was not explicitly stated, the authors either indicated “na” for not available, or if there was a corresponding value given for the “plan” versus the “actual”, or vice-versa, then it was used and tagged with a “*” in these tables. The information on the status of critical technologies being used by a program was derived from the “Technology Maturity” section of the 2-page summary.

Table A-1. U.S. GAO Selected Acquisition Report Data for 2012 from Associated 2-Page Summaries of MDAPs (47/48 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	B-2 Spirit	$710.0	$625.2	-11.9%	$33.81	$31.26	-7.5%	21	20	-4.8%	85	91	7.1%	EMD	0	6	100.0%
Navy	IDECM	$694.4	$821.5	18.3%	$4.34	$4.32	-0.4%	160	190	18.8%	59	54	-8.5%	EMD	0	0	100.0%
Army	Excalibur	$4,776.2	$1,780.5	-62.7%	$0.06	$0.24	283.9%	76677	7474	-90.3%	136	173	27.2%	EMD	0	1	100.0%
Navy	NMT	$2,321.0	$1,880.7	-19.0%	$6.97	$6.19	-11.2%	333	304	-8.7%	107	107	0.0%	PROD	0	2	100.0%
Navy	AARGM	$1,600.7	$1,902.3	18.8%	$0.89	$0.99	10.9%	1790	1919	7.2%	85	104	22.4%	PROD	0	2	100.0%
Navy	VTUAV	$2,615.4	$2,615.4	0.0%	$14.78	$14.95	1.1%	177	175	-1.1%	104	148	42.3%	PROD	0	0	100.0%
Army	JHSV	$3,636.4	$3,674.1	1.0%	$202.02	$204.12	1.0%	18	18	0.0%	48	50	4.2%	PROD	0	18	100.0%
Air Force	JASSM-ER	$3,730.5	$3,730.0	0.0%	$1.47	$1.47	0.0%	2531	2531	0.0%	na	na		PROD	0	5	100.0%
MDA	BMDS SM-3 Block IB	$4,006.7	$4,006.7	0.0%	$10.80*	$10.80	0.0%	370*	370	0.0%	na	na		EMD	0	5	100.0%
Air Force	GPS III	$3,941.4	$4,210.6	6.8%	$492.67	$526.32	6.8%	8	8	0.0%	na	na		PROD	0	8	100.0%
Navy	SSC	$4,412.9	$4,412.9	0.0%	$60.45*	$60.45	0.0%	73*	73	0.0%	135*	135	0.0%	TD	0	1	100.0%
Air Force	FAB-T	$3,188.5	$4,688.3	47.0%	$14.76	$19.06	29.1%	216	246	13.9%	129	174	34.9%	EMD	0	6	100.0%
Army	WIN-T Inc 2	$3,708.4	$6,052.7	63.2%	$1.96	$2.13	8.6%	1893	2846	50.3%	50	71	42.0%	PROD	0	15	100.0%
Air Force	C-130 AMP	$4,132.3	$6,204.3	50.1%	$7.96	$28.07	252.6%	519	221	-57.4%	na	na		PROD	0	3	100.0%
Navy	SM-6	$5,700.2	$6,296.7	10.5%	$4.75	$5.25	10.5%	1200	1200	0.0%	75	94	25.3%	PROD	0	7	100.0%
Army	JAGM	$6,880.0*	$6,880.0	0.0%	$0.19*	$0.19	0.0%	35422*	35422	0.0%	na	na		TD	0	5	100.0%
Navy	MUOS	$6,721.3	$6,978.2	3.8%	$1,120.22	$1,163.04	3.8%	6	6	0.0%	90	116	28.9%	PROD	0	8	100.0%
MDA	BMDS Aegis Ashore	$835.1	$1,418.6	69.9%	$417.57	$472.86	13.2%	2	3	50.0%	na	na		EMD	1	5	80.0%
Army	AH-64D Block IIIa	$7,242.5	$10,737.0	48.2%	$12.03	$16.80	39.7%	602	639	6.1%	79	82	3.8%	PROD	0	1	100.0%
Navy	LCS MM	$3,751.0	$2,888.4	-23.0%	$58.61*	$44.31*	-24.4%	64	65	1.6%	na	na		EMD	6	24	75.0%
Air Force	MQ-9	$2,637.1	$11,918.7	352.0%	$25.12	$29.87	18.9%	105	399	280.0%	79	94	19.0%	EMD	0	2	100.0%
Air Force	RQ-4A/4B	$5,392.0	$12,811.6	137.6%	$85.59	$232.94	172.2%	63	55	-12.7%	55	125	127.3%	PROD	0	10	100.0%
Navy	BAMS	$12,847.6	$13,052.4	1.6%	$183.54	$186.46	1.6%	70	70	0.0%	92	92	0.0%	EMD	0	1	100.0%
Air Force	HC/MC-130 Recap	$8,364.2	$13,090.8	56.5%	$113.03	$107.30	-5.1%	74	122	64.9%	na	na		PROD	0	2	100.0%
Navy	LHA 6	$3,180.2	$10,095.2	217.4%	$3,180.15	$3,365.05	5.8%	1	3	200.0%	146	165	13.0%	PROD	1	6	83.3%
Navy	E-2D AHE	$14,752.0	$17,747.3	20.3%	$196.69	$236.63	20.3%	75	75	0.0%	95	136	43.2%	PROD	0	5	100.0%
Air Force	SBIRS High	$4,596.5	$18,266.7	297.4%	$919.30	$3,044.44	231.2%	5	6	20.0%	86	86*	0.0%	PROD	0	3	100.0%
Army	JLENS	$6,665.9	$7,857.8	17.9%	$416.62	$491.11	17.9%	16	16	0.0%	97	103	6.2%	EMD	2	5	60.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
MDA	THAAD	$21,942.9*	$21,942.9	0.0%	na	na		na	na		na	na		PROD	0	50	100.0%
Army	Gray Eagle	$1,015.2	$5,158.9	408.2%	$203.05	$166.42	-18.0%	5	31	520.0%	50	50*	0.0%	PROD	3	5	40.0%
MDA	BMDS SM-3 Block IIA	$2,062.7	$2,521.8	22.3%	na	na		na	na		na	na		EMD	6	8	25.0%
Navy	P-8A MMA	$31,034.3	$32,969.3	6.2%	$269.86	$270.24	0.1%	115	122	6.1%	160	160	0.0%	PROD	0	1	100.0%
Navy	JPALS	$1,012.3	$983.3	-2.9%	$27.36	$26.58	-2.9%	37	37	0.0%	75	77	2.7%	EMD	2	2	0.0%
Air Force	GPS III OCX	$2,574.1	$2,574.1	0.0%	na	na		na	na		na	na		TD	14	14	0.0%
Air Force	SDB II	$4,702.1	$4,695.6	-0.1%	$0.27	$0.27	0.0%	17163	17163	0.0%	72	72	0.0%	EMD	4	4	0.0%
Navy	LCS	$1,358.6	$32,867.8	2319.2%	$339.60	$597.60	76.0%	4	55	1275.0%	41	116	182.9%	PROD	3	19	84.2%
Army	IAMD	$5,028.6	$5,528.8	9.9%	$16.99	$18.68	9.9%	296	296	0.0%	80	81	1.3%	EMD	4	4	0.0%
MDA	GMD	$39,161.8*	$39,161.8	0.0%	na	na		na	na		na	na		PROD	0	9	100.0%
Joint	JTRS AMF	$8,154.1	$8,160.8	0.1%	$0.30	$0.30	0.0%	27102	27102	0.0%	80	91	13.8%	EMD	5	5	0.0%
Joint	JTRS HMS	$10,037.5	$8,357.9	-16.7%	$0.03	$0.03	0.0%	328674	270951	-17.6%	85	104	22.4%	PROD	4	4	0.0%
Army	WIN-T Inc 3	$16,367.7	$13,871.4	-15.3%	$4.70	$4.33	-8.0%	3482	3207	-7.9%	165	187	13.3%	EMD	17	20	15.0%
Navy	DDG-1000	$34,800.0	$20,985.6	-39.7%	$1,087.50	$6,995.21	543.2%	32	3	-90.6%	128	222	73.4%	PROD	9	12	25.0%
Navy	AMDR	$15,837.3	$15,837.3	0.0%	$659.89*	$659.89	0.0%	24*	24	0.0%	149*	149	0.0%	TD	6	6	0.0%
Navy	CVN-21	$35,574.1	$33,993.6	-4.4%	$11,858.04	$11,331.19	-4.4%	3	3	0.0%	137	155	13.1%	PROD	7	13	46.2%
Marines	HLR	$16,557.1	$22,439.9	35.5%	$106.14	$112.20	5.7%	156	200	28.2%	119	157	31.9%	EMD	2	2	0.0%
Air Force	KC-46	$44,127.2	$44,127.2	0.0%	$246.52	$246.52	0.0%	179	179	0.0%	78	78	0.0%	EMD	3	3	0.0%
Joint	JSF	$213,708.2	$326,535.2	52.8%	$74.57	$132.90	78.2%	2866	2457	-14.3%	116	116*	0.0%	PROD	4	8	50.0%
Total Mean (2012)		**$638,096.2**	**$829,357.8**	**30.0%**	**$522.8**	**$717.9**	**37.3%**	**11,689.0**	**8,751.3**	**-25.1%**	**96.2**	**114.7**	**19.2%**		**103**	**345**	**70.1%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-2. U.S. GAO Selected Acquisition Report Data for 2011 from Associated 2-Page Summaries of MDAPs (49/49 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Army	Excalibur	$4,705.9	$1,670.9	-64.5%	$0.06	$0.24	288.5%	76677	7050	-90.8%	136	171	25.7%	PROD	0	3	100.0%
Army	IMS-Scorpion	$1,685.2	$1,685.2	0.0%	$0.64*	$0.64	0.0%	2624*	2624	0.0%	89*	89	0.0%	EMD	0	4	100.0%
Navy	NMT	$2,286.8	$1,804.7	-21.1%	$6.87	$5.94	-13.6%	333	304	-8.7%	107	107	0.0%	PROD	0	2	100.0%
Navy	AARGM	$1,577.2	$1,838.3	16.6%	$0.88	$0.96	8.7%	1790	1919	7.2%	85	85*	0.0%	PROD	0	2	100.0%
Navy	VTUAV	$2,576.3	$2,547.2	-1.1%	$14.56	$14.56	0.0%	177	175	-1.1%	104	141	35.6%	PROD	0	0	100.0%
Army	E-IBCT	$3,184.2	$3,257.6	2.3%	$353.80	$361.96	2.3%	9	9	0.0%	27	27	0.0%	PROD	0	10	100.0%
Army	JHSV	$3,582.5	$3,669.1	2.4%	$199.03	$203.84	2.4%	18	18	0.0%	48	50	4.2%	PROD	0	18	100.0%
Air Force	GPS IIIA	$3,883.1	$4,024.8	3.6%	$485.39	$503.10	3.6%	8	8	0.0%	na	na		EMD	0	5	100.0%
Army	WIN-T Inc 2	$3,653.3	$4,738.4	29.7%	$1.93	$2.14	10.8%	1893	2216	17.1%	50	65	30.0%	PROD	0	15	100.0%
Navy	LCS	$1,338.5	$1,338.5	0.0%	$334.62	$334.62*	0.0%	4	4*	0.0%	41	98	139.0%	PROD	3	19	84.2%
Air Force	C-130 AMP	$4,071.2	$5,995.6	47.3%	$7.84	$27.13	245.9%	519	221	-57.4%	na	na		PROD	0	3	100.0%
Navy	SM-6	$5,616.0	$6,132.8	9.2%	$4.68	$5.11	9.2%	1200	1200	0.0%	75	87	16.0%	PROD	0	7	100.0%
Navy	LHA 6	$3,133.0	$6,387.3	103.9%	$3,133.03	$3,193.64	1.9%	1	2	100.0%	146	159	8.9%	PROD	0	0	100.0%
Navy	MUOS	$6,622.0	$6,830.2	3.1%	$1,103.66	$1,138.36	3.1%	6	6	0.0%	90	112	24.4%	PROD	0	8	100.0%
Army	JAGM	$6,852.9	$6,852.9	0.0%	$0.20*	$0.20	0.0%	33853*	33853	0.0%	69*	69	0.0%	TD	0	3	100.0%
Air Force	JASSM	$2,281.6	$7,201.0	215.6%	$0.92	$1.44	55.3%	2469	5018	103.2%	75	87	16.0%	EMD	0	5	100.0%
Air Force	C-5 RERP	$10,743.7	$7,348.8	-31.6%	$85.27	$141.32	65.7%	126	52	-58.7%	100	135	35.0%	PROD	0	0	100.0%
Navy	LCS MM	$3,695.6	$3,695.6	0.0%	$57.74	$57.74*	0.0%	64	64*	0.0%	na	na		PROD	3	21	85.7%
Navy	MPF/MLP	$1,519.9	$1,519.9	0.0%	$506.62*	$506.62	0.0%	3*	3	0.0%	81*	81	0.0%	TD	1	4	75.0%
Air Force	MQ-9	$2,597.9	$11,131.8	328.5%	$24.74	$28.47	15.1%	105	391	272.4%	79	82	3.8%	PROD	0	4	100.0%
Army	AH-64D Block III	$7,135.1	$12,742.2	78.6%	$11.85	$18.33	54.7%	602	695	15.4%	79	82	3.8%	PROD	0	1	100.0%
Air Force	AEHF	$6,276.5	$12,919.6	105.8%	$1,255.31	$2,153.27	71.5%	5	6	20.0%	111	170	53.2%	PROD	0	14	100.0%
Navy	BAMS	$12,656.7	$13,031.5	3.0%	$180.81	$186.17	3.0%	70	70	0.0%	92	92	0.0%	EMD	0	0	100.0%
Air Force	FAB-T	$3,141.5	$3,929.9	25.1%	$14.54	$16.17	11.2%	216	243	12.5%	129	129*	0.0%	EMD	2	6	66.7%
Air Force	RQ-4A/4B	$5,312.4	$13,575.7	155.5%	$84.32	$176.31	109.1%	63	77	22.2%	55	55*	0.0%	PROD	0	10	100.0%
Marines	EFV	$9,018.7	$14,043.7	55.7%	$8.80	$23.68	169.1%	1025	593	-42.1%	138	257	86.2%	EMD	0	4	100.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	SBIRS High	$4,520.6	$15,938.5	252.6%	$904.11	$2,656.41	193.8%	5	6	20.0%	86	86*	0.0%	PROD	0	3	100.0%
Navy	E-2D AHE	$14,534.5	$17,830.7	22.7%	$193.79	$237.74	22.7%	75	75	0.0%	95	136	43.2%	PROD	0	5	100.0%
Army	MEADS	$19,077.3	$18,513.3	-3.0%	$397.44	$385.69	-3.0%	48	48	0.0%	157	157	0.0%	EMD	0	5	100.0%
MDA	THAAD	$21,156.2	$21,156.2	0.0%	na	na		na	na		na	na		PROD	0	50	100.0%
Army	JLENS	$6,566.9	$7,378.0	12.4%	$410.43	$461.12	12.4%	16	16	0.0%	97	97	0.0%	EMD	2	4	50.0%
Army	Gray Eagle	$1,000.2	$4,844.0	384.3%	$200.05	$372.61	86.3%	5	13	160.0%	50	87	74.0%	PROD	3	5	40.0%
Joint	JTRS GMR	$17,164.7	$15,867.7	-7.6%	$0.16	$0.18	15.2%	108388	87079	-19.7%	55	127	130.9%	EMD	8	19	57.9%
Joint	JTRS HMS	$9,889.2	$4,786.2	-51.6%	$0.03	$0.02	-26.7%	328674	215961	-34.3%	85	104	22.4%	EMD	5	6	16.7%
Air Force	B-2 Spirit	$699.4	$618.6	-11.6%	$33.30	$30.93	-7.1%	21	20	-4.8%	85	85	0.0%	EMD	6	6	0.0%
Navy	JPALS	$997.1	$976.2	-2.1%	$26.95	$26.38	-2.1%	37	37	0.0%	75	77	2.7%	EMD	2	2	0.0%
Air Force	GPS III OCX	$2,891.3	$2,891.3	0.0%	$1,445.64*	$1,445.64	0.0%	2*	2	0.0%	na	na		TD	14	14	0.0%
Navy	P-8A MMA	$30,575.9	$32,352.6	5.8%	$265.88	$265.19	-0.3%	115	122	6.1%	160	160	0.0%	PROD	0	1	100.0%
Navy	SSC	$4,343.7	$4,343.7	0.0%	$59.50*	$59.50	0.0%	73*	73	0.0%	na	na		TD	5	5	0.0%
Air Force	SDB II	$4,627.9	$4,627.9	0.0%	$0.27	$0.27	0.0%	17163	17163	0.0%	72	72	0.0%	EMD	4	4	0.0%
Army	IAMD	$4,954.0	$4,954.0	0.0%	$16.74	$16.74	0.0%	296	296	0.0%	80	80	0.0%	EMD	4	4	0.0%
Joint	JTRS AMF	$8,032.9	$8,211.8	2.2%	$0.30	$0.30	2.4%	27102	27102	0.0%	80	77	-3.8%	EMD	5	5	0.0%
Army	WIN-T Inc 3	$16,125.3	$13,666.0	-15.3%	$4.63	$4.26	-8.0%	3482	3207	-7.9%	165	187	13.3%	EMD	17	20	15.0%
MDA	GMD	$38,082.4	$38,082.4	0.0%	na	na		na	na		na	na		PROD	0	9	100.0%
Navy	CVN-21	$35,048.5	$34,185.7	-2.5%	$11,682.83	$11,395.25	-2.5%	3	3	0.0%	137	149	8.8%	PROD	7	13	46.2%
Marines	HLR	$16,311.5	$21,902.3	34.3%	$104.56	$109.51	4.7%	156	200	28.2%	119	153	28.6%	EMD	2	2	0.0%
Navy	DDG-1000	$34,283.9	$34,283.9	0.0%	$1,071.37	$1,071.37*	0.0%	32	32*	0.0%	128	221	72.7%	PROD	9	12	25.0%
Navy	SSN 774	$59,550.2	$83,569.4	40.3%	$1,985.0	$2,785.6	40.3%	30	30	0.0%	134	151	12.7%	PROD	1	1	0.0%
Joint	JSF	$210,557.6	$283,674.5	34.7%	$73.47	$115.46	57.2%	2866	2457	-14.3%	116	174	50.0%	PROD	3	8	62.5%
Total Mean (2011)		**$680,138.9**	**$834,568.1**	**22.7%**	**$569.2**	**$678.7**	**19.2%**	**11847.7**	**8913.1**	**-24.8%**	**93.9**	**113.8**	**21.1%**		**106**	**371**	**71.4%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-3. U.S. GAO Selected Acquisition Report Data for 2010 from Associated 2-Page Summaries of MDAPs (55/57 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	ASIP	$338.6	$493.6	45.8%	$123.40*	$123.40	0.0%	4*	4	0.0%	na	na		EMD	0	4	100.0%
Air Force	SBSS	$850.7	$873.2	2.6%	$850.70	$873.20	2.6%	1	1	0.0%	na	na		PROD	0	5	100.0%
Army	JHSV	$1,841.5*	$1,841.5	0.0%	$184.15*	$184.15	0.0%	10*	10	0.0%	77*	77	0.0%	PROD	0	18	100.0%
Navy	AARGM	$1,561.5	$1,958.4	25.4%	$0.77	$1.03	32.8%	1790	1911	6.8%	85	92*	8.2%	PROD	0	2	100.0%
Navy	VTUAV	$2,551.1	$2,195.4	-13.9%	$14.41	$12.55	-13.0%	177	175	-1.1%	104	119	14.4%	PROD	0	0	100.0%
Army	Excalibur	$4,659.3	$2,475.3	-46.9%	$0.06	$0.08	32.8%	76677	30544	-60.2%	136	159	16.9%	EMD	0	3	100.0%
Navy	LHA 6	$3,102.0	$3,102.0*	0.0%	$3,101.96	$3,101.96*	0.0%	1	1	0.0%	146	159	8.9%	PROD	0	0	100.0%
Army	WIN-T Inc2	$3,617.2	$3,466.9	-4.2%	$1.91	$1.98	3.8%	1893	1747	-7.7%	50	65	30.0%	EMD	0	15	100.0%
Army	ER/MP	$990.3	$3,480.2	251.4%	$198.06	$316.39	59.7%	5	11	120.0%	50	83	66.0%	PROD	0	4	100.0%
Air Force	GPS IIIA	$3,844.6	$3,680.9	-4.3%	$480.58	$460.12	-4.3%	8	8	0.0%	na	na		PROD	0	5	100.0%
Air Force	C-130 AMP	$4,030.8	$4,030.8*	0.0%	$7.77	$7.77*	0.0%	519	519*	0.0%	na	na		EMD	0	3	100.0%
Air Force	JASSM	$2,259.0	$5,768.7	155.4%	$0.92	$1.15	25.9%	2469	5006	102.8%	75	86	14.7%	PROD	0	3	100.0%
Navy	SM-6	$5,560.2	$5,913.2	6.3%	$4.63	$4.93	6.3%	1200	1200	0.0%	75	81	8.0%	PROD	0	7	100.0%
Navy	MUOS	$6,556.2	$6,556.2	0.0%	$1,092.70	$1,092.70*	0.0%	6	6*	0.0%	91	91*	0.0%	PROD	0	8	100.0%
Air Force	GPS	$6,064.1	$7,282.1	20.1%	$183.76	$220.67	20.1%	33	33	0.0%	na	na		TD	0	1	100.0%
Air Force	C-5 RERP	$10,637.2	$7,310.6	-31.3%	$84.42	$140.59	66.5%	126	52	-58.7%	100	139	39.0%	EMD	0	0	100.0%
Navy	LCS	$1,325.2	$5,113.4	285.9%	$331.30	$730.49	120.5%	4	7	75.0%	41	98	139.0%	PROD	2	19	89.5%
Navy	EA-18G	$8,755.3	$8,632.8	-1.4%	$97.28	$101.56	4.4%	90	85	-5.6%	70	69	-1.4%	PROD	0	2	100.0%
Air Force	MQ-9	$2,572.2	$9,124.0	254.7%	$24.50	$35.78	46.1%	105	255	142.9%	na	na		TD	0	4	100.0%
Navy	LCS MM	$3,658.8	$3,658.8*	0.0%	$57.17	$57.17*	0.0%	64	64*	0.0%	na	na		PROD	5	22	77.3%
Air Force	RQ-4A	$5,259.7	$9,901.9	88.3%	$83.49	$183.37	119.6%	63	54	-14.3%	55	55*	0.0%	PROD	0	10	100.0%
Air Force	AEHF	$6,214.5	$10,406.8	67.5%	$1,242.90	$2,601.71	109.3%	5	4	-20.0%	111	170	53.2%	PROD	0	14	100.0%
Navy	H-1	$3,536.7	$11,524.3	225.8%	$12.45	$32.65	162.2%	284	353	24.3%	105	142	35.2%	EMD	0	0	100.0%
Air Force	FAB-T	$3,110.4	$3,949.4	27.0%	$14.40	$16.25	12.9%	216	243	12.5%	129	129	0.0%	EMD	2	6	66.7%
Navy	BAMS	$12,531.2	$12,531.2	0.0%	$179.02	$179.02	0.0%	70	70	0.0%	92	92	0.0%	PROD	0	0	100.0%
NOAA	NPOESS	$6,519.1	$13,161.5	101.9%	$1,086.52	$3,290.38	202.8%	6	4	-33.3%	113	193	70.8%	EMD	0	7	100.0%
Air Force	SBIRS High	$4,471.1	$13,638.4	205.0%	$894.23	$3,409.61	281.3%	5	4	-20.0%	na	na		PROD	0	3	100.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Marines	EFV	$8,930.3	$14,286.7	60.0%	$8.71	$24.09	176.5%	1025	593	-42.1%	138	245	77.5%	PROD	0	4	100.0%
MDA	THAAD	$14,481.8*	$14,481.8	0.0%	na	na		na	na		na	na		EMD	0	50	100.0%
Navy	E-2D AHE	$14,390.8	$17,643.3	22.6%	$191.88	$235.24	22.6%	75	75	0.0%	95	136	43.2%	PROD	0	5	100.0%
Army	MEADS	$18,887.7	$17,981.5	-4.8%	$393.49	$374.61	-4.8%	48	48	0.0%	157	157	0.0%	EMD	0	5	100.0%
Navy	MPF/MLP	$3,538.2*	$3,538.2	0.0%	$1,179.38*	$1,179.38	0.0%	3*	3	0.0%	171*	171	0.0%	PROD	3	5	40.0%
Army	JLENS	$6,501.9	$7,067.3	8.7%	$406.37	$441.71	8.7%	16	16	0.0%	97	98	1.0%	EMD	2	4	50.0%
Joint	JTRS HMS	$9,790.9	$3,371.1	-65.6%	$0.03	$0.02	-46.7%	329574	215961	-34.5%	85	99	16.5%	EMD	5	6	16.7%
MDA	FTF	$630.9*	$630.9	0.0%	$105.15*	$105.15	0.0%	6*	6	0.0%	na	na		EMD	6	6	0.0%
Air Force	B-2 Spirit	$692.4	$644.8	-6.9%	$32.97	$32.24	-2.2%	21	20	-4.8%	85	85	0.0%	EMD	6	6	0.0%
Army	MIDS JTRS	$304.0	$707.5	132.7%	$9.50	$2.03	-78.6%	32	348	987.5%	50	69	38.0%	TD	4	4	0.0%
Navy	JPALS	$987.3	$987.3	0.0%	$26.68	$26.68	0.0%	37	37	0.0%	75	77	2.7%	PROD	2	2	0.0%
Joint	JTRS GMR	$16,994.9	$16,142.0	-5.0%	$0.16	$0.19	18.5%	108388	86643	-20.1%	55	114	107.3%	TD	8	20	60.0%
Navy	NMT	$2,264.2	$1,967.2	-13.1%	$6.80	$6.47	-4.8%	333	304	-8.7%	107	107	0.0%	EMD	2	2	0.0%
Joint	JTRS NED	$956.9	$2,018.7	111.0%	na	na		na	na		na	na		EMD	1	1	0.0%
MDA	Aegis BMD	$9,232.5	$9,232.5	0.0%	na	na		na	na		na	na		EMD	4	5	20.0%
MDA	ABL	$5,789.1	$5,789.1	0.0%	na	na		na	na		na	na		EMD	7	7	0.0%
Army	AH-64D Block III	$7,064.3	$7,956.9	12.6%	$11.74	$12.45	6.1%	602	639	6.1%	79	79	0.0%	PROD	1	1	0.0%
Joint	JTRS AMF	$8,098.4*	$8,098.4	0.0%	$0.30*	$0.30	0.0%	27102*	27102	0.0%	na	na		PROD	5	5	0.0%
MDA	GMD	$33,129.7*	$33,129.7	0.0%	na	na		na	na		na	na		EMD	0	9	100.0%
Army	WIN-T Inc3	$15,966.0	$15,966.0	0.0%	$4.59	$4.59	0.0%	3482	3482	0.0%	165	191	15.8%	PROD	17	20	15.0%
Marines	MRAP	$22,566.4	$37,781.6	67.4%	1.47	1.65	12.5%	15,374	22,882	48.8%	6	6	0.0%	PROD	0	0	100.0%
Marines	HLR	$16,149.7	$16,549.9	2.5%	103.52	106.09	2.5%	156	156	0.0%	119	122	2.5%	PROD	2	2	0.0%
Navy	P-8A MMA	$30,271.9	$30,271.9	0.0%	263.23	263.23*	0.0%	115	115*	0.0%	160	160*	0.0%	EMD	1	2	50.0%
Navy	CVN-21	$34,701.0	$31,089.6	-10.4%	11567.00	10363.20	-10.4%	3	3	0.0%	137	149	8.8%	PROD	8	13	38.5%
Navy	DDG-1000	$33,945.1	$33,945.1*	0.0%	1060.79	1060.79*	0.0%	32	32*	0.0%	128	128*	0.0%	PROD	9	12	25.0%
Navy	V-22	$39,112.3	$56,141.2	43.5%	42.84	122.58	186.1%	913	458	-49.8%	117	291	148.7%	PROD	0	0	100.0%
Navy	SSN 774	$58,957.7	$82,382.5	39.7%	1965.26	2746.08	39.7%	30	30	0.0%	134	151	12.7%	EMD	3	3	0.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Joint	JSF	$208,475.6	$247,221.3	18.6%	72.74	101.20	39.1%	2866	2443	-14.8%	116	137	18.1%	PROD	0	8	100.0%
Total Mean (2010)		**$739,230.4**	**$879,095.5**	**18.9%**	**$556.2**	**$687.8**	**23.7%**	**11521.3**	**8075.3**	**-29.9%**	**99.5**	**121.8**	**22.4%**		**105**	**372**	**71.8%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-4. U.S. GAO Selected Acquisition Report Data for 2009 from Associated 2-Page Summaries of MDAPs (59/60 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	SBSS	$842.3	$857.6	1.8%	$842.34	$857.62	1.8%	1	1	0.0%	na	na		PROD	0	5	100.0%
Air Force	B-2 RMP	$1,299.2	$1,237.4	-4.8%	$61.87	$61.87	0.0%	21	20	-4.8%	63	68	7.9%	PROD	0	4	100.0%
Army	MP-RTIP	$1,735.1	$1,334.5	-23.1%	na	na		na	na		na	na		EMD	0	8	100.0%
Air Force	C-5 AMP	$1,065.4	$1,469.8	38.0%	$8.46	$13.12	55.2%	126	112	-11.1%	83	97	16.9%	PROD	0	0	100.0%
Navy	AARGM	$1,546.0	$1,645.3	6.4%	$0.86	$0.86	-0.3%	1790	1911	6.8%	85	87	2.4%	PROD	0	2	100.0%
Army	Sky Warrior	$980.5	$2,339.2	138.6%	$196.11	$194.94	-0.6%	5	12	140.0%	50	96	92.0%	EMD	0	4	100.0%
Army	Excalibur	$4,613.1	$2,363.8	-48.8%	$0.06	$0.08	30.0%	76677	30388	-60.4%	136	153	12.5%	PROD	0	3	100.0%
Air Force	MQ-9	$704.0	$2,892.4	310.9%	$21.33	$24.51	14.9%	63	118	87.3%	70	66	-5.7%	PROD	0	4	100.0%
Navy	BAMS	$3,095.6*	$3,095.6	0.0%	$44.22*	$44.22	0.0%	70*	70	0.0%	92*	92	0.0%	EMD	0	0	100.0%
Navy	LHA 6	$3,071.5	$3,286.6	7.0%	$3,071.50	$3,286.59	7.0%	1	1	0.0%	146	151	3.4%	PROD	0	0	100.0%
Air Force	GPS IIIA	$3,806.9	$3,806.9	0.0%	$475.86	$475.86	0.0%	8	8	0.0%	na	na		EMD	0	5	100.0%
Army	ATIRCM/CMWS	$3,296.1	$4,811.7	46.0%	$1.07	$1.34	25.9%	3094	3589	16.0%	na	na		PROD	0	5	100.0%
Air Force	C-130 AMP	$3,991.3	$5,412.4	35.6%	$7.69	$24.49	218.5%	519	221	-57.4%	na	na		EMD	0	3	100.0%
Air Force	JASSM	$2,236.8	$5,712.0	155.4%	$0.91	$1.14	25.9%	2469	5006	102.8%	75	87	16.0%	PROD	0	3	100.0%
MDA	STSS	$6,723.0	$6,380.6	-5.1%	na	na		na	na		na	na		EMD	0	5	100.0%
Navy	MUOS	$6,491.6	$6,411.3	-1.2%	$1,081.93	$1,068.55	-1.2%	6	6	0.0%	91	102	12.1%	PROD	0	8	100.0%
Air Force	GPS	$6,004.5	$7,138.9	18.9%	$6,004.50	$7,138.90	18.9%	33	33	0.0%	na	na		EMD	0	1	100.0%
Air Force	C-5 RERP	$10,532.7	$7,289.5	-30.8%	$83.59	$140.18	67.7%	126	52	-58.7%	100	139	39.0%	PROD	0	0	100.0%
Air Force	TSAT	$7,801.9*	$7,801.9	0.0%	$1,560.38*	$1,560.38	0.0%	5*	5	0.0%	na	na		TD	0	7	100.0%
Navy	LCS	$1,312.1	$3,921.9	198.9%	$328.04	$560.28	70.8%	4	7	75.0%	41	85	107.3%	PROD	4	19	78.9%
Air Force	RQ-4A	$5,208.1	$9,699.4	86.2%	$82.67	$179.62	117.3%	63	54	-14.3%	55	55*	0.0%	PROD	0	10	100.0%
Navy	EA-18G	$8,669.1	$9,847.0	13.6%	$96.32	$111.90	16.2%	90	88	-2.2%	70	69	-1.4%	PROD	0	2	100.0%
Air Force	AEHF	$6,152.9	$10,303.7	67.5%	$1,230.58	$2,575.93	109.3%	5	4	-20.0%	111	170	53.2%	PROD	0	14	100.0%
MDA	Aegis BMD	$11,457.7	$11,291.5	-1.5%	na	na		na	na		na	na		PROD	0	4	100.0%
Navy	LCS MM	$3,622.8	$3,767.0	4.0%	$56.61	$58.86	4.0%	64	64	0.0%	na	na		EMD	8	25	68.0%
Marines	EFV	$8,841.5	$13,682.5	54.8%	$8.63	$23.07	167.5%	1025	593	-42.1%	138	245	77.5%	EMD	0	4	100.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
NOAA	NPOESS	$6,454.5	$10,912.6	69.1%	$1,075.76	$2,728.15	153.6%	6	4	-33.3%	172	193	12.2%	PROD	1	7	85.7%
MDA	THAAD	$15,123.7*	$15,123.7	0.0%	na	na		na	na		na	na		PROD	0	50	100.0%
Navy	E-2D AHE	$14,248.3	$15,610.6	9.6%	$189.98	$208.14	9.6%	75	75	0.0%	95	94	-1.1%	EMD	0	4	100.0%
Navy	MPF/MLP	$3,125.5*	$3,125.5	0.0%	$1,041.83*	$1,041.83	0.0%	3*	3	0.0%	na	na		TD	3	5	40.0%
Army	JLENS	$6,437.8	$6,700.3	4.1%	$402.36	$418.77	4.1%	16	16	0.0%	97	97	0.0%	EMD	2	4	50.0%
Air Force	SBIRS High	$4,427.4	$12,209.6	175.8%	$885.48	$3,052.41	244.7%	5	4	-20.0%	na	na		PROD	1	3	66.7%
Air Force	F-22A	$3,638.6	$5,920.8	62.7%	na	na		na	na		109	145	33.0%	EMD	2	3	33.3%
Army	WIN-T Inc2	$3,581.5	$3,581.5	0.0%	$1.89	$1.89	0.0%	1893	1893	0.0%	50	56	12.0%	EMD	12	15	20.0%
Joint	JTRS HMS	$9,694.5	$3,022.7	-68.8%	$0.03	$0.03	6.9%	329574	95961	-70.9%	85	93	9.4%	EMD	5	6	16.7%
Army	MIDS-JTRS	$301.0	$593.2	97.1%	$9.41	$1.54	-83.6%	32	385	1103.1%	50	62	24.0%	EMD	4	4	0.0%
Air Force	B-2 Spirit	$685.6	$695.4	1.4%	$32.65	$34.77	6.5%	21	20	-4.8%	85	85	0.0%	EMD	5	5	0.0%
MDA	FTF	$1,418.1*	$1,418.1	0.0%	$59.09*	$59.09	0.0%	24*	24	0.0%	na	na		EMD	6	6	0.0%
Joint	JTRS GMR	$16,826.6	$16,600.3	-1.3%	$0.16	$0.19	23.9%	108388	86652	-20.1%	55	114	107.3%	EMD	8	20	60.0%
Navy	NMT	$2,241.7	$1,943.3	-13.3%	$6.73	$6.39	-5.1%	333	304	-8.7%	107	107	0.0%	EMD	2	2	0.0%
Joint	JTRS NED	$947.4	$2,031.7	114.5%	na	na		na	na		na	na		EMD	1	1	0.0%
Marines	MRAP	$22,453.2	$27,642.1	23.1%	$1.46	$1.75	19.5%	15374	15838	3.0%	6	6	0.0%	PROD	0	0	100.0%
MDA	MKV	$3,216.1	$3,269.1	1.6%	na	na		na	na		na	na		TD	16	16	0.0%
Air Force	FAB-T	$3,079.6	$3,453.0	12.1%	$14.26	$15.55	9.1%	216	222	2.8%	129	129	0.0%	EMD	7	7	0.0%
MDA	KEI	$4,118.9	$4,212.0	2.3%	na	na		na	na		na	na		EMD	4	4	0.0%
Navy	VH-71	$6,523.9	$6,523.9*	0.0%	$283.65	$283.65*	0.0%	23	23*	0.0%	57	57*	0.0%	PROD	2	2	0.0%
Army	AH-64D Block III	$6,995.0	$7,719.9	10.4%	$11.62	$12.08	4.0%	602	639	6.1%	79	78	-1.3%	EMD	1	1	0.0%
Joint	JTRS AMF	$7,913.6*	$7,913.6	0.0%	$0.71*	$0.71	0.0%	11107*	11107	0.0%	na	na		EMD	5	5	0.0%
MDA	ABL	$8,289.9	$8,213.7	-0.9%	na	na		na	na		na	na		TD	7	7	0.0%
MDA	GMD	$35,533.1*z	$35,533.1	0.0%	na	na		na	na		na	na		EMD	0	9	100.0%
Marines	HLR	$15,991.1	$16,038.1	0.3%	$102.51	$102.81	0.3%	156	156	0.0%	119	117	-1.7%	EMD	2	2	0.0%
Navy	P-8A MMA	$29,974.0	$29,621.9	-1.2%	$260.64	$262.14	0.6%	115	113	-1.7%	160	160	0.0%	EMD	1	2	50.0%
Army	MEADS	$18,701.8	$17,884.6	-4.4%	$389.62	$372.60	-4.4%	48	48	0.0%	157	157	0.0%	EMD	4	4	0.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Navy	DDG-1000	$33,609.3	$27,611.3	-17.8%	$1,050.29	$3,944.47	275.6%	32	7	-78.1%	128	212	65.6%	PROD	8	12	33.3%
Navy	CVN-21	$34,360.3	$29,913.9	-12.9%	$11,453.45	$9,971.31	-12.9%	3	3	0.0%	137	149	8.8%	PROD	9	14	35.7%
Navy	V-22	$38,725.7	$55,544.0	43.4%	$42.42	$121.28	185.9%	913	458	-49.8%	117	294	151.3%	PROD	0	0	100.0%
Navy	SSN 774	$58,377.5	$81,556.2	39.7%	$1,945.92	$2,718.54	39.7%	30	30	0.0%	134	151	12.7%	EMD	3	3	0.0%
Army	FCS	$89,776.1	$129,730.6	44.5%	$5,985.08	$8,648.70	44.5%	15	15	0.0%	91	147	61.5%	EMD	41	44	6.8%
Joint	JSF	$206,410.3	$244,772.1	18.6%	$72.02	$99.66	38.4%	2866	2456	-14.3%	175	125	-28.6%	PROD	3	8	62.5%
Total Mean (2009)		**$828,303.3**	**$974,442.8**	**17.6%**	**$828.3**	**$1,071.7**	**29.4%**	**11391**	**5282**	**-53.6%**	**97**	**118**	**20.8%**		**177**	**420**	**57.9%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-5. U.S. GAO Selected Acquisition Report Data for 2008 from Associated 2-Page Summaries of MDAPs (72/72 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Marines	EFSS	$751.8	$272.7	-63.7%	$10.90	$3.90	-64.2%	69	70	1.4%	52	71	36.5%	PROD	0	0	100.0%
Navy	LCS MCM	$976.0*	$976.0	0.0%	$40.67*	$40.67	0.0%	24*	24	0.0%	na	na		EMD	0	11	100.0%
Air Force	B-2 RMP	$1,277.6	$1,132.5	-11.4%	$60.84	$53.93	-11.4%	21	21	0.0%	63	65	3.2%	EMD	0	4	100.0%
Air Force	C-5 AMP	$1,047.6	$1,450.5	38.5%	$8.31	$12.95	55.8%	126	112	-11.1%	83	97	16.9%	PROD	0	0	100.0%
Army	JHSV	$1,533.0*	$1,533.0	0.0%	$191.63*	$191.63	0.0%	8*	8	0.0%	na	na		EMD	0	0	100.0%
Army	LUH	$1,617.0	$1,792.8	10.9%	$5.02	$5.57	10.9%	322	322	0.0%	10	11	10.0%	PROD	0	5	100.0%
Army	DCGS-A	$1,844.3*	$1,844.3	0.0%	na	na		na	na		na	na		EMD	0	3	100.0%
Joint	JTRS AMF	$1,850.7*	$1,850.7*	0.0%	na	na		na	na		na	na		TD	0	0	100.0%
Joint	WGS	$1,132.5	$2,030.7	79.3%	$377.50	$406.15	7.6%	3	5	66.7%	50	94	88.0%	PROD	0	2	100.0%
Air Force	AF DCGS	$2,126.5	$2,126.5	0.0%	$2,126.52*	$2,126.52	0.0%	1*	1	0.0%	na	na		TD	0	0	100.0%
Air Force	MQ-9	$692.3	$2,234.6	222.8%	$20.98	$27.59	31.5%	63	81	28.6%	70	56	-20.0%	EMD	0	4	100.0%
Army	Excalibur	$4,536.1	$2,358.7	-48.0%	$0.06	$0.08	32.2%	76677	30388	-60.4%	136	149	9.6%	PROD	0	3	100.0%
Navy	MPF/MLP	$2,687.1	$2,687.1	0.0%	$895.70	$895.70	0.0%	3	3	0.0%	na	na		EMD	0	2	100.0%
Navy	BAMS	$2,830.5*	$2,830.5	0.0%	na	na		na	na		na	na		TD	0	0	100.0%
Navy	LHA 6	$3,020.3	$3,192.1	5.7%	$3,020.26	$3,192.09	5.7%	1	1	0.0%	146	151	3.4%	PROD	0	0	100.0%
Army	JCA	$3,783.1*	$3,783.1	0.0%	$48.50*	$48.50	0.0%	78*	78	0.0%	32*	32	0.0%	PROD	0	0	100.0%
Army	WIN-T Inc1	$3,889.0*	$3,889.0	0.0%	$2.32*	$2.32	0.0%	1677*	1677	0.0%	19*	19	0.0%	PROD	0	0	100.0%
Army	MP-RTIP	$1,706.1	$1,325.4	-22.3%	na	na		na	na		na	na		EMD	1	8	87.5%
Army	ATIRCM/CMWS	$3,241.7	$5,313.2	63.9%	$1.05	$1.48	41.2%	3094	3589	16.0%	na	na		PROD	0	5	100.0%
Air Force	C-130 AMP	$3,924.5	$5,348.4	36.3%	$7.56	$24.09	218.6%	519	222	-57.2%	na	na		EMD	0	6	100.0%
Air Force	JASSM	$2,200.9	$5,670.1	157.6%	$0.89	$1.13	27.2%	2469	5006	102.8%	75	87	16.0%	PROD	0	3	100.0%
Navy	MUOS	$6,383.4	$5,991.7	-6.1%	$1,063.89	$998.61	-6.1%	6	6	0.0%	91	91	0.0%	EMD	0	7	100.0%
MDA	STSS	$6,591.2*	$6,591.2	0.0%	na	na		2*	2	0.0%	na	na		EMD	0	5	100.0%
Navy	LCS SuW	$649.1*	$649.1	0.0%	$27.05	$27.05	0.0%	24	24	0.0%	na	na		EMD	1	4	75.0%
Air Force	AEHF	$6,050.0	$6,817.3	12.7%	$1,209.99	$2,272.44	87.8%	5	3	-40.0%	111	134	20.7%	PROD	0	14	100.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	GPS	$5,904.2	$7,056.7	19.5%	$178.92	$213.84	19.5%	33	33	0.0%	na	na		PROD	0	1	100.0%
Navy	EA-18G	$8,524.4	$8,127.9	-4.7%	$94.72	$101.60	7.3%	90	80	-11.1%	70	69	-1.4%	PROD	0	5	100.0%
Air Force	CSAR-X	$8,219.1	$8,219.1	0.0%	$57.08	$57.08	0.0%	144	144	0.0%	70	70	0.0%	EMD	0	8	100.0%
Navy	H-1	$3,444.1	$8,256.7	139.7%	$12.13	$29.07	139.7%	284	284	0.0%	105	143	36.2%	EMD	0	0	100.0%
Air Force	C-130J	$901.2	$8,929.5	890.8%	$81.93	$102.64	25.3%	11	87	690.9%	16	33	106.3%	PROD	0	0	100.0%
Navy	LCS	$1,304.6	$5,233.2	301.1%	$652.30	$348.88	-46.5%	2	15	650.0%	41	62	51.2%	PROD	4	19	78.9%
Air Force	SBIRS High	$4,365.2	$10,470.4	139.9%	$873.04	$3,490.13	299.8%	5	3	-40.0%	na	na		PROD	0	3	100.0%
Navy	LCS ASW	$912.7*	$912.7	0.0%	$57.05	$57.05	0.0%	16	16	0.0%	na	na		EMD	5	12	58.3%
MDA	Aegis BMD	$11,233.1	$11,233.1	0.0%	na	na		na	na		na	na		PROD	0	3	100.0%
Air Force	RQ-4A	$5,121.0	$9,599.8	87.5%	$81.29	$177.77	118.7%	63	54	-14.3%	55	55	0.0%	PROD	1	10	90.0%
Air Force	TSAT	$12,035.3*	$12,035.3	0.0%	$2,005.89*	$2,005.89	0.0%	6*	6	0.0%	99*	99	0.0%	TD	0	7	100.0%
Air Force	KC-X	$12,572.9*	$12,572.9	0.0%	$241.79*	$241.79	0.0%	52*	52	0.0%	69*	69	0.0%	TD	0	0	100.0%
Marines	MRAP	$13,501.4*	$13,501.4	0.0%	$1.43*	$1.43	0.0%	9439*	9439	0.0%	na	na		PROD	0	0	100.0%
Marines	EFV	$8,696.7	$13,504.4	55.3%	$8.49	$22.77	168.4%	1025	593	-42.1%	138	245	77.5%	EMD	0	4	100.0%
Army	Sky Warrior	$964.2	$1,536.7	59.4%	$192.84	$128.06	-33.6%	5	12	140.0%	50	59	18.0%	EMD	2	4	50.0%
Navy	ERM	$430.4	$1,359.1	215.8%	$0.05	$0.09	80.0%	8570	15100	76.2%	50	182	264.0%	EMD	9	17	47.1%
Air Force	SDB II	$765.4*	$765.4	0.0%	na	na		12046*	12046	0.0%	57*	57	0.0%	TD	3	5	40.0%
Air Force	C-5 RERP	$10,356.7	$15,283.9	47.6%	$82.20	$137.69	67.5%	126	111	-11.9%	100	139	39.0%	EMD	0	0	100.0%
MDA	THAAD	$15,561.4*	$15,561.4	0.0%	na	na		na	na		na	na		EMD	0	50	100.0%
Army	ARH	$3,407.7	$5,728.3	68.1%	$9.26	$11.19	20.8%	368	512	39.1%	47	72	53.2%	EMD	1	2	50.0%
Navy	VH-71	$6,415.1	$6,415.1*	0.0%	$278.92	$278.92*	0.0%	23	23*	0.0%	57	57*	0.0%	PROD	1	2	50.0%
NOAA	NPOESS	$6,346.6	$10,709.1	68.7%	$1,057.76	$2,677.29	153.1%	6	4	-33.3%	172	200	16.3%	PROD	3	7	57.1%
Army	WIN-T Inc2	$3,528.4*	$3,528.4	0.0%	$2.32	$2.32	0.0%	1677	1677	0.0%	19	19	0.0%	PROD	9	12	25.0%
Air Force	F-22A	$3,584.9	$5,907.6	64.8%	$13.13	$34.15	160.1%	273	173	-36.6%	133	133	0.0%	EMD	3	4	25.0%
Army	MIDS	$295.1	$622.6	111.0%	$9.22	$1.44	-84.4%	32	433	1253.1%	50	50	0.0%	EMD	4	4	0.0%
Air Force	B-2 Spirit	$675.5	$675.5	0.0%	$32.17	$32.17	0.0%	21	21	0.0%	85	85	0.0%	EMD	5	5	0.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Joint	JTRS GMR	$16,545.0	$15,483.7	-6.4%	$0.15	$0.15	-3.3%	108388	104425	-3.7%	55	114	107.3%	EMD	8	20	60.0%
Army	JLENS	$6,330.5	$6,416.8	1.4%	$395.66	$401.05	1.4%	16	16	0.0%	97	97	0.0%	EMD	4	5	20.0%
MDA	MKV	$3,197.6*	$3,196.6	0.0%	na	na		na	na		na	na		EMD	15	16	6.3%
Air Force	FAB-T	$3,028.1	$3,354.7	10.8%	$14.02	$15.11	7.8%	216	222	2.8%	129	129	0.0%	EMD	7	7	0.0%
MDA	KEI	$4,038.2*	$4,038.2	0.0%	na	na		na	na		na	na		EMD	21	21	0.0%
Joint	JTRS HMS	$9,532.8	$9,703.6	1.8%	$0.03	$0.03	0.0%	329574	329574	0.0%	85	93	9.4%	EMD	5	6	16.7%
Army	AH-64D Block III	$6,878.3	$7,471.2	8.6%	$11.43	$11.69	2.3%	602	639	6.1%	79	78	-1.3%	EMD	1	1	0.0%
MDA	ABL	$8,127.4*	$8,127.4	0.0%	na	na		na	na		na	na		EMD	7	7	0.0%
Air Force	EELV	$16,500.9	$32,281.2	95.6%	$91.17	$233.92	156.6%	181	138	-23.8%	120*	120	0.0%	PROD	0	0	100.0%
Navy	E-2D AHE	$14,009.9	$15,317.7	9.3%	$186.80	$204.24	9.3%	75	75	0.0%	95	94	-1.1%	EMD	3	4	25.0%
Army	MEADS	$18,389.7	$17,598.3	-4.3%	$383.12	$366.63	-4.3%	48	48	0.0%	158	157	-0.6%	EMD	4	6	33.3%
MDA	GMD	$37,334.2*	$37,334.2	0.0%	na	na		na	na		na	na		PROD	0	9	100.0%
Marines	HLR	$15,724.7	$15,823.8	0.6%	$100.80	$101.43	0.6%	156	156	0.0%	119	117	-1.7%	EMD	3	3	0.0%
Joint	SR	$19,400.4*	$19,400.4	0.0%	$1,940.04	$1,940.04	0.0%	10	10	0.0%	na	na		TD	5	5	0.0%
Navy	CVN-21	$33,786.0	$29,735.8	-12.0%	$11,262.00	$9,911.95	-12.0%	3	3	0.0%	137	149	8.8%	PROD	10	15	33.3%
Navy	P-8A MMA	$29,473.8	$28,773.6	-2.4%	$256.29	$252.40	-1.5%	115	114	-0.9%	160	160	0.0%	EMD	3	4	25.0%
Navy	DDG-1000	$33,076.9	$33,076.9	0.0%	$3,307.69	$3,307.69	0.0%	10*	10	0.0%	128	192	50.0%	PROD	9	12	25.0%
Navy	V-22	$38,080.5	$54,767.3	43.8%	$41.71	$119.58	186.7%	913	458	-49.8%	117	295	152.1%	PROD	0	0	100.0%
Navy	SSN 774	$57,407.3	$81,251.4	41.5%	$1,913.58	$2,708.38	41.5%	30	30	0.0%	134	148	10.4%	EMD	3	3	0.0%
Army	FCS	$88,278.7	$128,483.8	45.5%	$5,885.25	$8,565.59	45.5%	15	15	0.0%	91	145	59.3%	EMD	42	44	4.5%
Joint	JSF	$202,956.7	$239,974.3	18.2%	$70.82	$97.63	37.9%	2866	2458	-14.2%	175	196	12.0%	PROD	6	8	25.0%
Total Mean (2008)		**$877,507.2**	**$1,063,048.3**	**21.1%**	**$683.4**	**$812.1**	**18.8%**	**9,076**	**8,402**	**-7.4%**	**88**	**107**	**21.8%**		**208**	**466**	**55.4%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-6. U.S. GAO Selected Acquisition Report Data for 2007 from Associated 2-Page Summaries of MDAPs (62/62 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Marines	EFSS	$727.7	$744.3	2.3%	$10.55	$10.63	0.8%	69	70	1.4%	52	52	0.0%	PROD	0	0	100.0%
Air Force	C-5 AMP	$1,014.0	$911.0	-10.2%	$8.05	$14.93	85.6%	126	61	-51.6%	83	94	13.3%	PROD	0	0	100.0%
Navy	BAMS	$1,230.9	$1,230.9	0.0%	na	na		na	na		70*	70	0.0%	TD	0	0	100.0%
Joint	JTRS AMF	$1,476.2	$1,476.2	0.0%	na	na		1344*	1344	0.0%	na	na		TD	0	0	100.0%
Army	LUH	$1,574.4	$1,671.0	6.1%	$4.89	$5.19	6.2%	322	322	0.0%	10	11	10.0%	PROD	0	5	100.0%
Joint	WGS	$1,096.4	$2,013.2	83.6%	$365.47	$402.64	10.2%	3	5	66.7%	50	93	86.0%	PROD	0	2	100.0%
Army	Excalibur	$788.9	$2,063.7	161.6%	$0.00	$0.07	1600.0%	200000	30294	-84.9%	160	136	-15.0%	PROD	0	3	100.0%
Navy	AESA	$2,372.8	$2,470.5	4.1%	$5.72	$5.95	4.1%	415	415	0.0%	69	72	4.3%	PROD	0	4	100.0%
Navy	LHA 6	$2,940.6	$2,940.6	0.0%	$2,940.62*	$2,940.62	0.0%	1*	1	0.0%	146*	146	0.0%	PROD	0	0	100.0%
Army	LW/DBCS	$2,692.8	$3,504.0	30.1%	$0.17	$0.14	-16.1%	15985	24849	55.5%	145	175	20.7%	EMD	0	3	100.0%
Navy	AMCM	$1,522.9	$1,298.2	-14.8%	na	na		231	144	-37.7%	na	na		PROD	5	38	86.8%
Air Force	C-130 AMP	$3,798.9	$4,537.7	19.4%	$7.32	$10.46	42.8%	519	434	-16.4%	na	na		EMD	0	6	100.0%
MDA	STSS	$3,461.2	$4,682.9	35.3%	na	na		na	na		na	na		EMD	0	5	100.0%
Air Force	MQ-9	$670.1	$782.2	16.7%	na	na		63	63	0.0%	70	70	0.0%	EMD	1	4	75.0%
Air Force	GPS	$5,715.1	$6,922.6	21.1%	na	na		33	40	21.2%	na	na		PROD	0	1	100.0%
Air Force	AEHF	$5,856.7	$6,266.7	7.0%	$1,171.33	$2,088.90	78.3%	5	3	-40.0%	111	134	20.7%	PROD	1	14	92.9%
Air Force	C-130J	$872.5	$7,886.0	803.8%	$79.32	$99.82	25.9%	11	79	618.2%	16	33	106.3%	PROD	0	0	100.0%
Navy	MUOS	$6,179.2	$5,459.2	-11.7%	$1,029.87	$909.86	-11.7%	6	6	0.0%	91	91	0.0%	EMD	1	9	88.9%
Air Force	CSAR-X	$8,461.6	$8,461.6	0.0%	$58.76*	$58.76	0.0%	144*	144	0.0%	70*	70	0.0%	EMD	0	8	100.0%
Air Force	RQ-4A	$4,957.0	$9,083.2	83.2%	$78.68	$168.21	113.8%	63	54	-14.3%	55	78	41.8%	PROD	0	10	100.0%
Navy	ERM	$416.7	$1,426.8	242.4%	$0.05	$0.09	91.8%	8570	15100	76.2%	50	182	264.0%	PROD	6	17	64.7%
Air Force	C-5 RERP	$10,025.1	$9,673.7	-3.5%	$79.56	$87.15	9.5%	126	111	-11.9%	100	125	25.0%	EMD	0	0	100.0%
Air Force	SBIRS High	$4,225.9	$10,436.4	147.0%	$845.18	$3,478.79	311.6%	5	3	-40.0%	na	na		PROD	0	3	100.0%
Marines	EFV	$8,418.2	$11,254.9	33.7%	$8.21	$10.98	33.7%	1025	1025	0.0%	138	189	37.0%	EMD	0	5	100.0%
Air Force	B-2 RMP	$1,236.7	$1,153.4	-6.7%	$58.89	$54.92	-6.7%	21	21	0.0%	63	63*	0.0%	EMD	2	4	50.0%
MDA	THAAD	$12,309.7	$12,455.0	1.2%	na	na		na	na		na	na		EMD	0	0	100.0%
Army	UAS	$933.3	$1,825.0	95.5%	$186.67	$152.09	-18.5%	5	12	140.0%	50	59	18.0%	EMD	2	4	50.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	SDB II	$858.3	$858.3	0.0%	na	na		12000*	12000	0.0%	100*	100	0.0%	TD	3	5	40.0%
Air Force	F-22A	$3,501.0	$4,285.0	22.4%	$12.82	$24.77	93.1%	273	173	-36.6%	133	133	0.0%	EMD	3	6	50.0%
Navy	LCS	$1,262.9	$7,686.5	508.6%	$631.43	$512.43	-18.8%	2	15	650.0%	41	46	12.2%	PROD	14	36	61.1%
Navy	VH-71	$6,210.0	$6,210.0	0.0%	$270.00*	$270.00	0.0%	23*	23	0.0%	57*	57	0.0%	PROD	1	2	50.0%
Air Force	E-10A TDP	$2,057.6	$2,057.6	0.0%	$2,057.65	$2,057.65	0.0%	1	1	0.0%	na	na		TD	13	18	27.8%
Navy	MRUUVS	$430.8	$430.8	0.0%	na	na		na	na		59*	59	0.0%	TD	5	6	16.7%
Army	ACS	$4,236.6	$1,170.9	-72.4%	$111.49	$30.81	-72.4%	38	38	0.0%	127	127*	0.0%	TD	5	6	16.7%
NOAA	NPOESS	$6,143.8	$10,437.0	69.9%	$1,023.96	$2,609.25	154.8%	6	4	-33.3%	172	235	36.6%	PROD	3	7	57.1%
Joint	JTRS HMS	$9,227.9	$9,400.4	1.9%	$0.03	$0.03	3.6%	329574	329574	0.0%	85	82	-3.5%	EMD	3	6	50.0%
Joint	JTRS GMR	$16,016.4	$15,006.9	-6.3%	$0.15	$0.14	-2.7%	108388	104425	-3.7%	55	117	112.7%	EMD	7	20	65.0%
Navy	SSN 774	$641.2	$641.2	0.0%	na	na		na	na		na	na		EMD	3	3	0.0%
Army	APKWS II	$1,505.0	$1,505.0	0.0%	$0.02	$0.02	0.0%	71637	71637	0.0%	62	62	0.0%	EMD	1	1	0.0%
Navy	ABMD	$7,371.5	$9,038.8	22.6%	na	na		na	na		na	na		PROD	2	3	33.3%
MDA	MKV	$1,721.1	$1,721.1	0.0%	na	na		na	na		na	na		TD	18	18	0.0%
Army	JLENS	$6,128.2	$6,262.8	2.2%	$383.01	$391.43	2.2%	69*	16	16.0%	52*	97	97.0%	EMD	4	5	20.0%
MDA	KEI	$8,984.7	$2,334.8	-74.0%	na	na		na	na		na	na		EMD	7	7	0.0%
Army	ARH	$3,298.9	$3,309.8	0.3%	$8.96	$8.99	0.3%	368	368	0.0%	47	47	0.0%	EMD	2	2	0.0%
Air Force	TSAT	$17,715.7	$17,715.7	0.0%	$2,952.60	$2,952.60*	0.0%	6	6*	0.0%	147	147*	0.0%	TD	3	7	57.1%
Army	ATIRCM/CMWS	$3,138.4	$5,046.8	60.8%	$1.01	$1.41	38.7%	3094	3589	16.0%	na	na		PROD	5	5	0.0%
Air Force	ABL	$5,749.7	$5,449.2	-5.2%	na	na		na	na		na	na		EMD	7	7	0.0%
Air Force	EELV	$15,974.4	$28,580.0	78.9%	$88.26	$207.10	134.7%	181	138	-23.8%	na	na		PROD	0	0	100.0%
Army	AH-64D Block III	$6,697.0	$6,697.0	0.0%	$11.13*	$11.13	0.0%	602*	602	0.0%	78*	78	0.0%	EMD	1	1	0.0%
Navy	E-2D AHE	$13,562.2	$13,605.0	0.3%	$108.83	$181.40	66.7%	75	75	0.0%	95	94	-1.1%	EMD	3	4	25.0%
Navy	EA-18G	$8,251.8	$8,550.9	3.6%	$91.69	$106.89	16.6%	90	80	-11.1%	70	69	-1.4%	EMD	5	5	0.0%
Army	MEADS	$17,801.5	$17,304.9	-2.8%	$370.87	$360.52	-2.8%	48	48	0.0%	158	157	-0.6%	EMD	4	6	33.3%
Army	WIN-T	$10,835.8	$11,601.6	7.1%	$10,835.79	$11,601.60	7.1%	1	1	0.0%	78	133	70.5%	EMD	12	12	0.0%
MDA	GMD	$23,776.5	$30,667.9	29.0%	na	na		na	na		na	na		PROD	4	13	69.2%
Marines	HLR	$15,306.6	$15,306.6	0.0%	$95.07*	$95.07	0.0%	161*	161	0.0%	117*	117	0.0%	EMD	3	3	0.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Joint	SR	$23,326.3	$17,992.6	-22.9%	$1,060.29	$1,799.26	69.7%	22	10	-54.5%	na	na		TD	5	5	0.0%
Navy	CVN-21	$32,704.2	$30,059.1	-8.1%	$10,901.40	$10,019.71	-8.1%	3	3	0.0%	137	149	8.8%	EMD	13	17	23.5%
Navy	DDG-1000	$2,094.3	$33,099.7	1480.5%	$3,309.97*	$3,309.97	0.0%	10*	10	0.0%	128	192	50.0%	EMD	9	12	25.0%
Navy	V-22	$36,863.7	$49,974.1	35.6%	$40.38	$109.11	170.2%	913	458	-49.8%	117	293	150.4%	PROD	0	0	100.0%
Navy	P-8A MMA	$28,531.1	$27,880.7	-2.3%	$248.10	$244.57	-1.4%	115	114	-0.9%	160	160	0.0%	EMD	4	4	0.0%
Army	FCS	$85,456.9	$131,663.1	54.1%	$5,697.13	$8,777.54	54.1%	15	15	0.0%	91	139	52.7%	EMD	45	46	2.2%
Joint	JSF	$196,472.2	$223,795.7	13.9%	$68.55	$91.05	32.8%	2866	2458	-14.2%	185	196	5.9%	EMD	6	8	25.0%
Total Mean (2007)		**$718,829.7**	**$879,978.4**	**22.4%**	**$1,006.8**	**$1,197.3**	**18.9%**	**14609**	**11551**	**-20.9%**	**92**	**112**	**21.2%**		**241**	**451**	**46.6%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-7. U.S. GAO Selected Acquisition Report Data for 2006 from Associated 2-Page Summaries of MDAPs (51/52 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	C-5 AMP	$979.7	$860.5	-12.2%	$7.78	$14.59	87.6%	126	59	-53.2%	83	90	8.4%	PROD	0	0	100.0%
Air Force	B-2 RMP	$1,194.8	$1,143.8	-4.3%	$56.89	$54.47	-4.3%	21	21	0.0%	63	63	0.0%	EMD	0	4	100.0%
Air Force	SDB	$1,648.7	$1,629.0	-1.2%	$0.07	$0.07	0.0%	24070	24070	0.0%	62	61	-1.6%	PROD	0	6	100.0%
Air Force	WGS	$1,059.2	$1,805.5	70.5%	$353.08	$361.09	2.3%	3	5	66.7%	50	93	86.0%	PROD	0	2	100.0%
Army	Excalibur	$762.2	$1,992.0	161.3%	$0.00	$0.07	1550.0%	200000	30269	-84.9%	160	136	-15.0%	PROD	0	3	100.0%
Navy	AESA	$2,292.6	$2,419.1	5.5%	$5.52	$5.83	5.5%	415	415	0.0%	69	68	-1.4%	PROD	0	4	100.0%
Army	JTRS AMF	$2,730.5*	$2,730.5	0.0%	na	na		3338*	3338	0.0%	na	na		TD	0	0	100.0%
Air Force	C-130 AMP	$3,670.5	$4,094.1	11.5%	$7.07	$8.81	24.5%	519	465	-10.4%	na	na		EMD	0	6	100.0%
Army	ATIRCM/CMWS	$3,032.1	$4,813.6	58.8%	$0.98	$1.34	36.8%	3094	3589	16.0%	na	na		PROD	0	5	100.0%
Air Force	MQ-9	$703.2	$778.8	10.8%	na	na		63	63	0.0%	70	70	0.0%	EMD	1	4	75.0%
Air Force	AEHF	$5,657.8	$6,249.9	10.5%	$1,131.57	$2,083.29	84.1%	5	3	-40.0%	111	134	20.7%	PROD	0	14	100.0%
Air Force	GPS	$5,522.0	$6,637.7	20.2%	$167.33	$165.94	-0.8%	33	40	21.2%	na	na		PROD	0	1	100.0%
Navy	ASDS	$291.4	$652.5	123.9%	$97.13	$652.48	571.7%	3	1	-66.7%	na	na		EMD	1	3	66.7%
MDA	Aegis BMD	$7,213.0	$8,489.9	17.7%	na	na		65*	65	0.0%	na	na		PROD	0	3	100.0%
Navy	MUOS	$5,969.6	$5,373.7	-10.0%	$994.93	$895.61	-10.0%	6	6	0.0%	91	91	0.0%	EMD	2	11	81.8%
Army	Land Warrior	$2,601.5	$9,274.6	256.5%	$0.16	$0.11	-33.1%	15985	85412	434.3%	145	163	12.4%	EMD	0	3	100.0%
Air Force	C-5 RERP	$9,686.2	$9,511.9	-1.8%	$76.88	$84.93	10.5%	126	112	-11.1%	100	125	25.0%	EMD	0	0	100.0%
Air Force	SBIRS High	$4,079.4	$10,168.1	149.3%	$815.89	$3,389.37	315.4%	5	3	-40.0%	na	na		PROD	0	3	100.0%
Army	CH-47	$2,859.6	$10,832.9	278.8%	$9.47	$21.16	123.4%	302	512	69.5%	82	114	39.0%	PROD	0	0	100.0%
Marines	EFV	$8,133.8	$11,052.5	35.9%	$7.94	$10.78	35.9%	1025	1025	0.0%	138	186	34.8%	EMD	0	5	100.0%
MDA	THAAD	$11,498.7	$12,045.1	4.8%	na	na		na	na		na	na		EMD	0	50	100.0%
Army	Warrior	$901.7	$1,744.0	93.4%	$180.34	$145.33	-19.4%	5	12	140.0%	50	56	12.0%	EMD	2	4	50.0%
MDA	STSS	$3,386.8	$4,582.7	35.3%	na	na		2	2	0.0%	na	na		EMD	2	5	60.0%
Navy	LCS	$1,220.0	$1,906.2	56.2%	$610.02	$476.44	-21.9%	2	4	100.0%	41	29	-29.3%	PROD	22	41	46.3%
Army	AH-64D	$1,931.6	$1,931.6	0.0%	$17.56	$17.56	0.0%	110	110	0.0%	66	66	0.0%	TD	9	15	40.0%
Navy	VH-71A	$5,999.4	$5,999.4	0.0%	$260.84	$260.84	0.0%	23	23	0.0%	57	57	0.0%	PROD	1	2	50.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	Global Hawk	$4,789.5	$6,352.4	32.6%	$76.02	$124.56	63.8%	63	51	-19.0%	55	57	3.6%	PROD	7	13	46.2%
Army	ACS	$4,093.0	$4,049.2	-1.1%	$107.71	$106.56	-1.1%	38	38	0.0%	127	127	0.0%	EMD	5	6	16.7%
Navy	ADS	$1,318.0*	$1,318.0	0.0%	$87.87*	$87.87	0.0%	15*	15	0.0%	25*	25	0.0%	EMD	4	4	0.0%
Army	APKWS	$1,881.8	$1,476.2	-21.6%	$0.02	$0.02	0.0%	89420	71565	-20.0%	60	102	70.0%	EMD	1	1	0.0%
Army	JLENS	$5,967.0*	$5,967.0	0.0%	$372.94*	$372.94	0.0%	16*	16	0.0%	97*	97	0.0%	EMD	4	5	20.0%
MDA	ABL	$5,626.1	$5,639.4	0.2%	na	na		na	na		na	na		EMD	6	7	14.3%
Army	JTRS	$15,473.9	$16,218.6	4.8%	$0.14	$0.15	3.5%	108388	109921	1.4%	55	55*	0.0%	EMD	7	20	65.0%
MDA	KEI	$8,791.5	$2,838.2	-67.7%	na	na		8*	8	0.0%	na	na		EMD	7	7	0.0%
Air Force	J-UCAS	$4,151.4	$2,898.9	-30.2%	$691.90	$579.78	-16.2%	6	5	-16.7%	na	na		TD	8	8	0.0%
Air Force	TSAT	$17,114.2*	$17,114.2	0.0%	$2,852.37*	$2,852.37	0.0%	6*	6	0.0%	147*	147	0.0%	TD	3	7	57.1%
Army	JTRS Cluster 5	$8,914.9	$8,914.9	0.0%	$0.03	$0.03	0.0%	329574	329574	0.0%	85	85	0.0%	EMD	5	6	16.7%
Army	WIN-T	$10,468.9	$10,757.6	2.8%	$10,468.88	$10,757.64	2.8%	1	1	0.0%	78	78*	0.0%	EMD	9	12	25.0%
Navy	DD(X)	$2,023.8	$8,111.5	300.8%	na	na		na	na		128	180	40.6%	PROD	11	12	8.3%
Air Force	NPOESS	$5,935.2	$7,967.5	34.2%	$989.20	$1,327.91	34.2%	6	6	0.0%	172	180	4.7%	PROD	13	14	7.1%
Air Force	EELV	$15,433.7	$27,979.6	81.3%	$85.27	$202.75	137.8%	181	138	-23.8%	na	na		PROD	0	0	100.0%
Navy	E-2D AHE	$13,102.5	$13,283.6	1.4%	$174.70	$177.12	1.4%	75	75	0.0%	95	94	-1.1%	EMD	3	4	25.0%
Army	MEADS	$17,197.8	$16,762.2	-2.5%	$358.29	$349.21	-2.5%	48	48	0.0%	158	157	-0.6%	EMD	4	6	33.3%
MDA	GMD	$23,265.3	$29,167.0	25.4%	na	na		na	na		na	na		PROD	4	10	60.0%
Air Force	SR	$23,338.0*	$23,338.0	0.0%	$1,060.82*	$1,060.82	0.0%	22*	22	0.0%	170*	170	0.0%	TD	5	5	0.0%
Navy	CVN-21	$31,598.8	$29,953.1	-5.2%	$10,532.94	$9,984.37	-5.2%	3	3	0.0%	183	195	6.6%	EMD	15	18	16.7%
Navy	MMA	$27,563.5	$27,243.9	-1.2%	$239.68	$236.90	-1.2%	115	115	0.0%	160	160	0.0%	EMD	4	4	0.0%
Marines	V-22	$35,621.6	$48,946.7	37.4%	$39.02	$106.87	173.9%	913	458	-49.8%	117	291	148.7%	PROD	0	0	100.0%
Air Force	F-22A	$81,102.4	$65,396.9	-19.4%	$125.16	$361.31	188.7%	648	181	-72.1%	203	231	13.8%	PROD	0	3	100.0%
Army	FCS	$82,561.9	$127,504.6	54.4%	$5,504.13	$8,500.31	54.4%	15	15	0.0%	91	139	52.7%	EMD	53	54	1.9%
Air Force	F-35	$189,814.1	$206,339.2	8.7%	$66.23	$83.95	26.7%	2866	2458	-14.2%	185	196	5.9%	EMD	7	8	12.5%
Total Mean (2006)		**$732,174.8**	**$844,258.0**	**15.3%**	**$919.9**	**$1,093.4**	**18.9%**	**16633**	**14135**	**-15.0%**	**103**	**118**	**14.1%**		**225**	**428**	**47.4%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-8. U.S. GAO Selected Acquisition Report Data for 2005 from Associated 2-Page Summaries of MDAPs (54/54 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	C-5 AMP	$947.4	$779.3	-17.7%	$7.52	$14.17	88.4%	126	55	-56.3%	83	83	0.0%	PROD	0	0	100.0%
Air Force	JSOW	$4,372.2	$1,174.2	-73.1%	$0.56	$0.39	-30.3%	7800	3000	-61.5%	89	117	31.5%	PROD	0	1	100.0%
Air Force	WGS	$1,024.2	$1,521.3	48.5%	$341.41	$304.26	-10.9%	3	5	66.7%	50	75	50.0%	PROD	0	2	100.0%
Air Force	SDB	$1,594.2	$1,619.5	1.6%	$0.07	$0.07	1.5%	24070	24070	0.0%	62	61	-1.6%	EMD	0	6	100.0%
Navy	AESA	$2,217.0	$2,628.3	18.6%	$5.34	$6.33	18.6%	415	415	0.0%	69	68	-1.4%	PROD	0	4	100.0%
Army	ATIRCM/CMWS	$2,931.8	$2,868.9	-2.1%	$0.95	$1.08	13.4%	3094	2668	-13.8%	na	na		PROD	0	5	100.0%
Navy	Tomahawk	$1,817.5	$3,213.8	76.8%	$1.33	$1.15	-13.4%	1365	2790	104.4%	58	71	22.4%	PROD	0	3	100.0%
Air Force	JASSM	$1,990.6	$3,768.8	89.3%	$0.81	$0.86	7.1%	2469	4366	76.8%	75	87	16.0%	PROD	0	3	100.0%
Navy	CEC	$2,528.0	$4,696.2	85.8%	$13.81	$16.59	20.1%	183	283	54.6%	16	16	0.0%	PROD	0	6	100.0%
Air Force	AEHF	$5,471.8	$5,003.7	-8.6%	$1,094.36	$1,667.91	52.4%	5	3	-40.0%	111	118	6.3%	PROD	0	14	100.0%
Air Force	MQ-9	$626.1*	$626.1	0.0%	$9.94*	$9.94	0.0%	63*	63	0.0%	70*	70	0.0%	EMD	1	4	75.0%
Air Force	GPS	$5,339.7	$5,987.5	12.1%	$161.81	$161.83	0.0%	33	37	12.1%	na	na		PROD	0	1	100.0%
Army	CH-47	$2,765.3	$6,393.6	131.2%	$9.16	$18.86	106.0%	302	339	12.3%	82	113	37.8%	PROD	0	0	100.0%
MDA	STSS	$3,320.4*	$3,320.4	0.0%	na	na		2*	2	0.0%	na	na		EMD	1	5	80.0%
Air Force	C-130 AMP	$3,549.3	$4,170.9	17.5%	$6.84	$8.51	24.5%	519	490	-5.6%	na	na		EMD	1	6	83.3%
Navy	ERGM	$389.3	$598.4	53.7%	$0.05	$0.19	324.4%	8570	3141	-63.3%	50	150	200.0%	EMD	7	20	65.0%
MDA	Aegis BMD	$7,071.6	$7,878.9	11.4%	na	na		65*	65	0.0%	na	na		EMD	0	3	100.0%
Navy	ASDS	$281.7	$1,876.6	566.2%	$93.91	$312.76	233.0%	3	6	100.0%	na	na		EMD	1	3	66.7%
Navy	MUOS	$6,579.0	$6,579.0	0.0%	$1,096.50*	$1,096.50	0.0%	6*	6	0.0%	91*	91	0.0%	EMD	1	9	88.9%
Air Force	C-5 RERP	$9,366.5	$9,105.9	-2.8%	$74.34	$81.30	9.4%	126	112	-11.1%	100	116	16.0%	EMD	0	0	100.0%
Marines	EFV	$7,864.7	$9,517.4	21.0%	$7.67	$9.29	21.0%	1025	1025	0.0%	138	165	19.6%	EMD	0	5	100.0%
Air Force	SBIRS High	$3,948.0	$9,866.7	149.9%	$789.60	$1,973.33	149.9%	5	5	0.0%	na	na		PROD	0	3	100.0%
MDA	THAAD	$10,909.5	$11,273.3	3.3%	na	na		na	na		na	na		EMD	0	50	100.0%
Air Force	B-2 RMP	$1,403.5*	$1,403.5	0.0%	$66.83*	$66.83	0.0%	21*	21	0.0%	63*	63	0.0%	EMD	2	4	50.0%
Air Force	E-10A	$7,381.4*	$7,381.4	0.0%	$1,054.49*	$1,054.49	0.0%	7*	7	0.0%	na	na		TD	3	9	66.7%
Navy	LCS	$1,940.5	$2,037.8	5.0%	$485.14	$509.45	5.0%	4	4	0.0%	41	41	0.0%	PROD	28	42	33.3%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	Global Hawk	$4,631.4	$6,025.8	30.1%	$73.52	$118.15	60.7%	63	51	-19.0%	54	57	5.6%	PROD	9	14	35.7%
Army	Land Warrior	$2,515.6	$9,197.1	265.6%	$0.16	$0.16	-0.6%	15985	59038	269.3%	145	166	14.5%	EMD	2	4	50.0%
Navy	AMNS	$148.7	$189.1	27.2%	$3.16	$3.10	-2.0%	47	61	29.8%	50	50	0.0%	EMD	4	4	0.0%
Army	CKEM	$229.2*	$229.2	0.0%	na	na		na	na		na	na		TD	4	4	0.0%
Army	APKWS	$1,820.0	$1,778.9	-2.3%	$0.02	$0.02	0.0%	89420	89539	0.1%	60	69	15.0%	EMD	1	1	0.0%
MDA	ABL	$5,515.8	$5,055.3	-8.3%	na	na		na	na		na	na		EMD	6	7	14.3%
Marines	HLR	$3,130.2*	$3,130.2	0.0%	na	na		11*	11	0.0%	126*	126	0.0%	TD	3	3	0.0%
Army	Excalibur	$737.0	$3,426.0	364.9%	$0.00	$0.06	1275.0%	200000	61752	-69.1%	160	136	-15.0%	EMD	3	3	0.0%
Air Force	J-UCAS	$4,042.0	$4,042.0	0.0%	na	na		6*	6	0.0%	na	na		TD	6	6	0.0%
Air Force	NPOESS	$5,740.0	$6,115.9	6.5%	$956.68	$1,019.31	6.5%	6	6	0.0%	172	175	1.7%	PROD	13	14	7.1%
Army	JTRS Cluster 5	$8,680.1*	$8,680.1	0.0%	$0.03*	$0.03	0.0%	329574*	329574	0.0%	34*	34	0.0%	EMD	5	6	16.7%
Army	WIN-T	$10,123.0	$10,365.0	2.4%	$10,123.04	$10,365.01	2.4%	1	1	0.0%	78	78	0.0%	EMD	9	12	25.0%
Army	JCM	$6,858.8*	$6,858.8	0.0%	$0.14*	$0.14	0.0%	48815*	48815	0.0%	65*	65	0.0%	EMD	3	3	0.0%
MDA	KEI	$8,619.2	$7,771.2	-9.8%	na	na		8	8	0.0%	na	na		EMD	7	7	0.0%
Navy	EA-18G	$7,762.0*	$7,827.5	0.8%	$86.24	$86.97	0.8%	90	90	0.0%	70	69	-1.4%	EMD	5	5	0.0%
Navy	E-2 AHE	$12,671.0	$12,846.1	1.4%	$168.95	$171.28	1.4%	75	75	0.0%	95	94	-1.1%	EMD	3	4	25.0%
Air Force	EELV	$14,923.9	$27,745.5	85.9%	$82.45	$201.05	143.8%	181	138	-23.8%	na	na		PROD	0	0	100.0%
Navy	DD(X)	$1,956.5	$10,120.9	417.3%	na	na		1	1	0.0%	128	180	40.6%	EMD	12	12	0.0%
Army	MEADS	$16,744.8*	$16,744.8	0.0%	$348.85*	$348.85	0.0%	48*	48	0.0%	158*	158	0.0%	EMD	4	6	33.3%
Air Force	TSAT	$16,114.6	$16,114.6	0.0%	$2,685.77	$2,685.77	0.0%	6	6	0.0%	117	122	4.3%	EMD	6	7	14.3%
Army	JTRS	$14,963.9	$15,570.0	4.1%	$0.14	$0.14	3.6%	108388	109002	0.6%	55	60	9.1%	EMD	20	20	0.0%
MDA	GMD	$22,809.3	$25,719.9	12.8%	na	na		na	na		na	na		EMD	7	10	30.0%
Navy	CVN-21	$30,555.9*	$30,555.9	0.0%	$10,185.32*	$10,185.32	0.0%	3*	3	0.0%	183*	183	0.0%	EMD	11	14	21.4%
Marines	V-22	$34,442.5	$46,293.8	34.4%	$37.72	$101.08	167.9%	913	458	-49.8%	117	288	146.2%	EMD	0	0	100.0%
Navy	MMA	$26,837.5*	$26,837.5	0.0%	$233.37*	$233.37	0.0%	115*	115	0.0%	160*	160	0.0%	EMD	4	4	0.0%
Air Force	F/A-22	$78,405.1	$73,098.5	-6.8%	$121.00	$262.00	116.5%	648	279	-56.9%	203	230	13.3%	PROD	0	3	100.0%
Army	FCS	$79,835.8	$107,967.2	35.2%	$5,322.39	$7,197.81	35.2%	15	15	0.0%	91	139	52.7%	EMD	53	54	1.9%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	F-35	$183,561.2	$198,624.5	8.2%	$64.05	$80.84	26.2%	2866	2457	-14.3%	185	196	5.9%	EMD	6	8	25.0%
Total Mean (2005)		**$702,006.2**	**$804,222.7**	**14.6%**	**$814.0**	**$917.6**	**12.7%**	**16951**	**14891**	**-12.2%**	**96**	**111**	**15.6%**		**251**	**443**	**43.3%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-9. U.S. GAO Selected Acquisition Report Data for 2004 from Associated 2-Page Summaries of MDAPs (51/51 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Air Force	C-5 AMP	$935.2	$772.4	-17.4%	$7.42	$14.04	89.2%	126	55	-56.3%	83	83	0.0%	EMD	0	0	100.0%
Army	RQ-7A	$629.2	$777.1	23.5%	$14.30	$18.95	32.5%	44	41	-6.8%	51	43	-15.7%	PROD	0	5	100.0%
Air Force	JHMCS	$642.7	$1,112.8	73.1%	$0.33	$0.53	63.0%	1965	2087	6.2%	na	na		PROD	0	6	100.0%
Air Force	JSOW	$4,316.0	$1,161.8	-73.1%	$0.55	$0.39	-30.0%	7800	3000	-61.5%	89	117	31.5%	PROD	0	1	100.0%
Air Force	B-2 RMP	$1,278.6	$1,278.6	0.0%	$60.89	$60.89	0.0%	21	21	0.0%	72	72	0.0%	TD	0	2	100.0%
Air Force	WGS	$1,011.1	$1,488.8	47.2%	$337.05	$297.75	-11.7%	3	5	66.7%	50	77	54.0%	PROD	0	2	100.0%
Air Force	SDB	$1,573.8	$1,573.8	0.0%	$0.07	$0.07	0.0%	24070	24070	0.0%	61	61	0.0%	EMD	0	8	100.0%
Air Force	MM III PRP	$2,388.2	$2,260.2	-5.4%	$3.93	$3.76	-4.4%	607	601	-1.0%	90	90	0.0%	PROD	0	0	100.0%
Air Force	MM III GRP	$1,708.6	$2,533.3	48.3%	$2.62	$3.89	48.2%	652	652	0.0%	55	83	50.9%	PROD	0	0	100.0%
Navy	AESA	$2,217.0	$2,628.3	18.6%	$1.32*	$1.32	0.0%	415*	415	0.0%	69	67	-2.9%	PROD	0	4	100.0%
Navy	Tomahawk	$1,794.2	$2,838.4	58.2%	$1.31	$1.19	-9.8%	1365	2396	75.5%	58	71	22.4%	PROD	0	3	100.0%
Army	ATIRCM/CMWS	$2,894.1	$3,297.6	13.9%	$0.94	$1.22	30.5%	3094	2704	-12.6%	na	na		PROD	0	5	100.0%
Air Force	JASSM	$1,964.8	$3,765.4	91.6%	$0.80	$0.85	6.7%	2469	4434	79.6%	75	86	14.7%	PROD	0	3	100.0%
Navy	CEC	$2,495.4	$4,497.5	80.2%	$13.64	$14.94	9.6%	183	301	64.5%	16	16	0.0%	PROD	0	6	100.0%
Navy	ERGM	$384.3	$508.6	32.3%	$0.05	$0.16	260.0%	8570	3135	-63.4%	49	121	146.9%	EMD	5	20	75.0%
Air Force	MQ-9	$664.1*	$664.1	0.0%	$10.71*	$10.71	0.0%	62*	62	0.0%	71*	71	0.0%	TD	1	4	75.0%
Army	CH-47	$2,729.7	$6,183.5	126.5%	$9.04	$18.24	101.8%	302	339	12.3%	81	119	46.9%	PROD	0	0	100.0%
Air Force	C-130 AMP	$3,503.5	$4,090.9	16.8%	$6.75	$8.35	23.7%	519	490	-5.6%	na	na		EMD	1	6	83.3%
MDA	Aegis BMD	$6,981.1*	$6,981.1	0.0%	na	na		na	na		na	na		EMD	0	0	100.0%
Air Force	AEHF	$5,401.3	$4,829.8	-10.6%	$1,080.25	$1,609.92	49.0%	5	3	-40.0%	111	118	6.3%	EMD	3	14	78.6%
Air Force	SBIRS High	$4,132.4	$8,462.7	104.8%	$826.48	$1,692.54	104.8%	5	5	0.0%	86	147	70.9%	PROD	0	3	100.0%
Air Force	NPOESS	$5,666.1	$6,217.0	9.7%	$944.34	$1,036.17	9.7%	6	6	0.0%	172	172	0.0%	EMD	2	14	85.7%
Air Force	C-5 RERP	$9,245.5	$8,989.8	-2.8%	$73.38	$80.30	9.4%	126	112	-11.1%	100	103	3.0%	EMD	0	0	100.0%
Air Force	E-10A	$3,556.2*	$3,556.2	0.0%	$1,185.40*	$1,185.40	0.0%	3*	3	0.0%	101*	101	0.0%	EMD	3	9	66.7%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Navy	LCS	$874.7*	$874.7	0.0%	$437.34*	$437.34	0.0%	2*	2	0.0%	31*	31	0.0%	TD	12	22	45.5%
MDA	THAAD	$10,769.8*	$10,769.8	0.0%	na	na		na	na		na	na		EMD	0	50	100.0%
Marines	EFV	$7,763.7	$9,436.0	21.5%	$7.57	$9.21	21.5%	1025	1025	0.0%	138	162	17.4%	EMD	1	5	80.0%
Navy	ASDS	$278.1	$1,865.5	570.8%	$92.70	$310.92	235.4%	3	6	100.0%	na	na		EMD	2	3	33.3%
Army	PAC-3	$6,737.7	$12,959.8	92.3%	$5.62	$10.12	80.2%	1200	1281	6.8%	66	135	104.5%	PROD	0	0	100.0%
Navy	LMRS	$267.6	$557.1	108.2%	$38.22	$42.86	12.1%	7	13	85.7%	100	103	3.0%	EMD	2	2	0.0%
MDA	STSS	$6,122.6*	$6,122.6	0.0%	$3,061.31*	$3,061.31	0.0%	2*	2	0.0%	na	na		EMD	4	6	33.3%
Air Force	Global Hawk	$4,571.6	$5,516.8	20.7%	$72.57	$108.17	49.1%	63	51	-19.0%	54	57	5.6%	PROD	10	14	28.6%
Army	APKWS	$1,800.2	$1,800.2	0.0%	$0.02	$0.02	0.0%	89420	89420	0.0%	59	59	0.0%	EMD	1	1	0.0%
Air Force	EELV	$14,731.1	$18,443.5	25.2%	$81.39	$101.34	24.5%	181	182	0.6%	na	na		PROD	0	0	100.0%
Army	JCM	$2,896.1*	$2,896.1	0.0%	$0.26*	$0.26	0.0%	11361*	11361	0.0%	65*	65	0.0%	TD	3	3	0.0%
MDA	ABL	$5,471.1*	$5,471.1	0.0%	$5,471.13*	$5,471.13	0.0%	1*	1	0.0%	na	na		EMD	6	7	14.3%
Army	Excalibur	$727.6	$4,057.8	457.7%	$0.00	$0.05	1225.0%	200000	76677	-61.7%	160	136	-15.0%	EMD	3	3	0.0%
Navy	MUOS	$5,790.0	$5,649.0	-2.4%	$643.33	$941.50	46.3%	9	6	-33.3%	69	81	17.4%	TD	8	8	0.0%
Army	WIN-T	$10,013.1	$10,013.1	0.0%	$10,013.09	$10,013.09	0.0%	1	1	0.0%	77	77	0.0%	EMD	9	12	25.0%
Navy	EA-18G	$7,662.6*	$7,662.6	0.0%	$85.14	$85.14	0.0%	90	90	0.0%	68	68	0.0%	EMD	5	5	0.0%
Navy	CVN-21	$2,229.4	$12,087.9	442.2%	$12,087.85*	$12,087.85	0.0%	1*	1	0.0%	165	177	7.3%	TD	10	13	23.1%
Navy	DD(X)	$1,931.3	$10,046.6	420.2%	$10,046.58*	$10,046.58	0.0%	1*	1	0.0%	128	180	40.6%	TD	12	12	0.0%
Navy	E-2 AHE	$12,794.9	$12,792.0	0.0%	$170.60	$170.56	0.0%	75	75	0.0%	95	94	-1.1%	EMD	4	4	0.0%
Army	JTRS	$14,771.0	$14,687.5	-0.6%	$0.14	$0.14	-0.7%	108388	108414	0.0%	55	58	5.5%	EMD	20	20	0.0%
Air Force	AWS/TSAT	$8,281.0	$20,528.1	147.9%	$2,070.24	$2,052.81	-0.8%	4	10	150.0%	75	95	26.7%	EMD	4	5	20.0%
MDA	GMD	$22,517.3	$22,517.3	0.0%	$22,517.30*	$22,517.30	0.0%	1*	1	0.0%	na	na		EMD	7	10	30.0%
Army	RAH-66	$39,865.6	$34,577.0	-13.3%	$32.87	$53.20	61.9%	1213	650	-46.4%	223	256	14.8%	EMD	1	8	87.5%
Marines	V-22	$34,000.9	$46,025.9	35.4%	$37.24	$100.49	169.8%	913	458	-49.8%	117	297	153.8%	EMD	0	0	100.0%
Air Force	F/A-22	$77,398.2	$72,217.4	-6.7%	$119.44	$258.84	116.7%	648	279	-56.9%	203	230	13.3%	PROD	0	3	100.0%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Army	FCS	$78,968.7	$78,968.7	0.0%	$5,264.58	$5,264.58	0.0%	15	15	0.0%	91	91	0.0%	EMD	48	52	7.7%
Air Force	F-35	$181,195.0	$165,279.2	-8.8%	$63.22	$67.27	6.4%	2866	2457	-14.3%	185	185	0.0%	EMD	6	8	25.0%
Total Mean (2004)		**$628,544.0**	**$674,293.0**	**7.3%**	**$1,571.5**	**$1,617.8**	**3.0%**	**9590**	**6886**	**-28.2%**	**92**	**109**	**18.4%**		**193**	**391**	**50.6%**

*- Author estimate; U.S. GAO did not provide data within report.

Table A-10. U.S. GAO Selected Acquisition Report Data for 2003 from Associated 2-Page Summaries of MDAPs (26/26 programs represented)

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Joint	JSOW	$4,196.6	$1,115.3	-73.4%	$0.54	$0.37	-30.9%	7800	3000	-61.5%	89	112	25.8%	EMD	0	1	100.0%
Air Force	WGS	$1,012.7	$1,634.6	61.4%	$337.60	$326.90	-3.2%	3	5	66.7%	50	55	10.0%	PROD	0	2	100.0%
Navy	Tomahawk	$1,795.9	$2,130.0	18.6%	$1.32	$1.24	-6.2%	1365	1725	26.4%	58	69	19.0%	PROD	0	3	100.0%
Army	ATIRCM/CMWS	$2,906.9	$2,512.0	-13.6%	$0.94	$2.33	147.9%	3094	1078	-65.2%	na	na		EMD	0	5	100.0%
Joint	AIM-9X	$2,693.0	$2,649.6	-1.6%	$0.27	$0.26	-2.6%	10049	10142	0.9%	92	105	14.1%	PROD	0	0*	100.0%
Joint	JASSM	$1,962.9	$3,777.8	92.5%	$0.80	$0.85	7.2%	2469	4434	79.6%	75	87	16.0%	PROD	0	3	100.0%
Navy	CEC	$2,493.9	$4,180.4	67.6%	$13.60	$15.40	13.2%	183	272	48.6%	16	16	0.0%	PROD	0	6	100.0%
Joint	JPATS	$3,138.6	$4,674.8	48.9%	$4.41	$5.97	35.4%	712	783	10.0%	97	113	16.5%	PROD	0	0	100.0%
Navy	ERGM	$386.0	$485.5	25.8%	$0.05	$0.15	233.3%	8570	3230	-62.3%	50	121	142.0%	EMD	6	20	70.0%
Army	CH-47	$2,761.9	$6,097.3	120.8%	$9.15	$17.99	96.7%	302	339	12.3%	82	99	20.7%	PROD	0	0*	100.0%
Air Force	AEHF	$5,625.5	$5,117.5	-9.0%	$1,125.10	$1,705.80	51.6%	5	3	-40.0%	111	118	6.3%	PROD	1	12	91.7%
Air Force	SBIRS High	$4,127.0	$8,241.2	99.7%	$825.40	$1,648.20	99.7%	5	5	0.0%	na	na		EMD	0	3	100.0%
NOAA	NPOESS	$5,628.2	$6,183.4	9.9%	$938.00	$1,030.60	9.9%	6	6	0.0%	172	174	1.2%	EMD	2	14	85.7%
Marines	AAAV	$7,732.7	$8,440.9	9.2%	$7.54	$8.24	9.2%	1025	1025	0.0%	138	150	8.7%	EMD	1	5	80.0%
Army	PAC-3	$6,482.6	$12,381.2	91.0%	$5.17	$10.33	99.7%	1254	1199	-4.4%	66	136	106.1%	PROD	0	0*	100.0%
Navy	AESA	$518.9*	$494.2*	-4.8%	na	na		na	na		69	68	-1.4%	EMD	4	4	0.0%
MDA	ABL	$5,571.1*	$5,571.1	0.0%	$795.90	$795.90*	0.0%	7	7*	0.0%	118	118*	0.0%	TD	4	5	20.0%
Joint	JCM	$2,161.2	$2,161.2	0.0%	na	na		8425*	8425	0.0%	60*	60	0.0%	TD	3	3	0.0%
Air Force	AWS	$8,158.4	$8,158.4*	0.0%	$2,039.60	$2,039.60*	0.0%	4	4*	0.0%	75	75*	0.0%	TD	4	5	20.0%
Army	Excalibur	$736.0	$4,798.7	552.0%	$0.00	$0.06	1450.0%	200000	77677	-61.2%	160	136	-15.0%	EMD	3	3	0.0%
MDA	THAAD	$4,382.7*	$10,548.0*	140.7%	na	na		na	na		114	114	0.0%	EMD	4	4	0.0%
Army	RAH-66	$39,824.0	$34,545.0	-13.3%	$32.83	$53.15	61.9%	1213	650	-46.4%	222	250	12.6%	EMD	1	8	87.5%

Service	Program	Total Program Cost			Unit Cost			Units Planned			Acquisition Cycle Time			Acquisition Phase	Critical Technologies		
		Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change	Estimated	Actual	Change		Immature	Total	Mature
Marines	V-22	$33,264.7	$42,617.5	28.1%	$36.43	$93.05	155.4%	913	458	-49.8%	117	261	123.1%	PROD	0	0*	100.0%
Navy	F/A-18E/F	$67,389.7	$47,549.8	-29.4%	$67.39	$86.77	28.8%	1000	548	-45.2%	102	112	9.8%	PROD	0	0*	100.0%
Air Force	F/A-22	$75,461.0	$70,469.4	-6.6%	$116.50	$253.50	117.6%	648	278	-57.1%	203	230	13.3%	PROD	0	3	100.0%
Joint	F-35	$180,047.0	$180,485.5	0.2%	$62.80	$63.00	0.3%	2866	2866	0.0%	185	185	0.0%	EMD	6	8	25.0%
Total Mean (2003)		**$470,459.1**	**$477,020.3**	**1.4%**	**$279.2**	**$354.8**	**27.1%**	**10497**	**4923**	**-53.1%**	**105**	**124**	**17.6%**		**39**	**117**	**66.7%**

*- Author estimate; U.S. GAO did not provide data within report.